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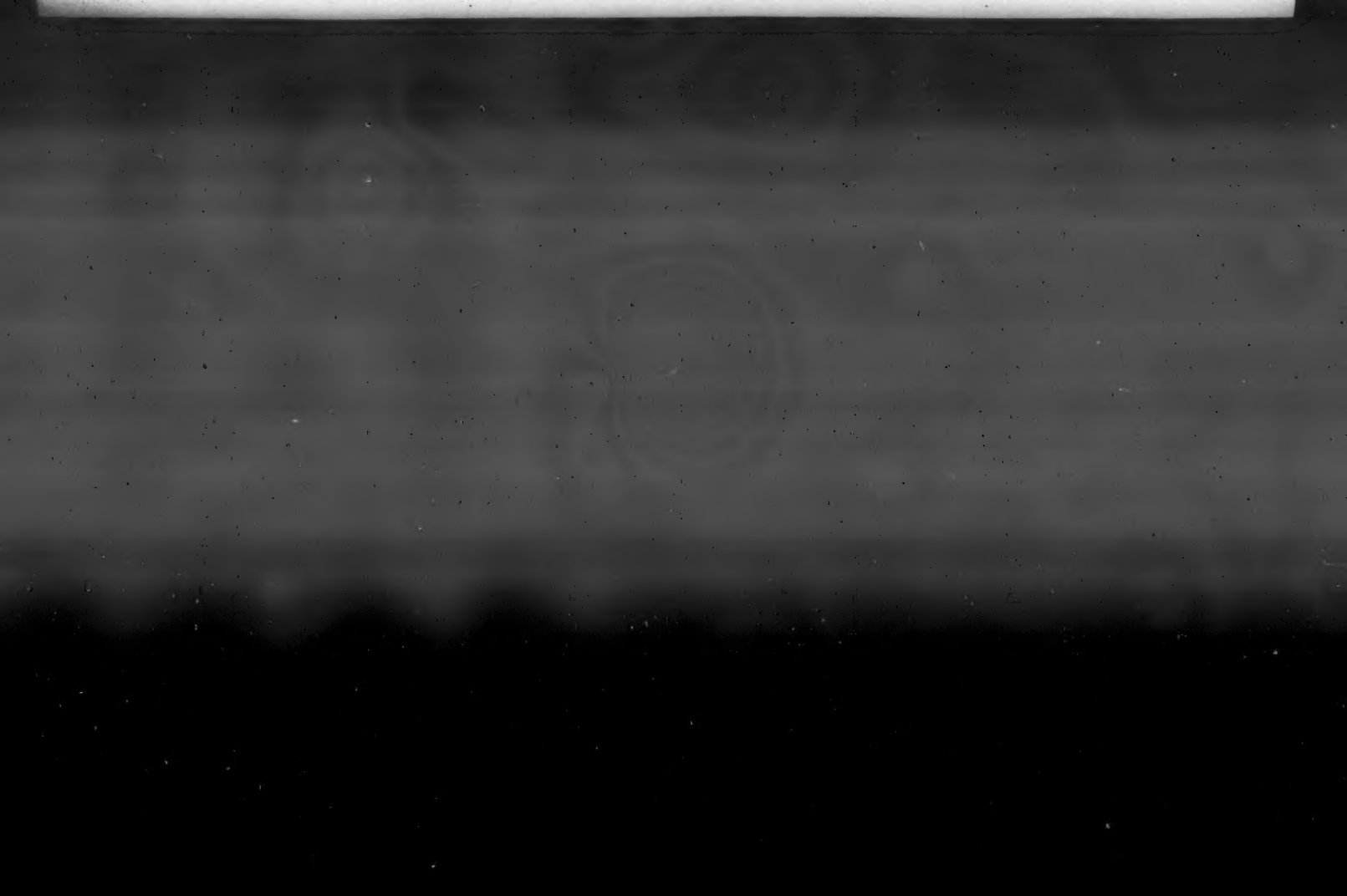


THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XXV.—*The Gulf of Mexico as a Measure of Isostasy*; by W. J. McGEE.

I.

THE now venerable James Hall was one of the first geologists to observe that areas of rapid deposition are areas of subsidence. When Powell extended his early surveys into western America he observed the converse relation, namely, that areas of degradation are areas of elevation. As the geodetic surveys of Great Britain, India and the European continent yielded data for determining the distribution of density in the earth, Pratt and afterward Fisher and others observed that the sea bottoms are heavy, the continents lighter, the mountain ranges lightest of all. Meantime and subsequently the original observations were repeated and extended in different lands until the observed relations were found to be general; meantime also the relation of coexistence was inferred to be one of sequence, and thus it came to be recognized that mountains are high because they are light, that sea bottoms are low because they are heavy, that areas of degradation rise because of unloading, and that areas of deposition subside because of loading—i. e. it came to be recognized that the entire terrestrial crust is in a condition analogous to that of hydrostatic equilibrium. This subject has been profoundly studied by Dutton, who invented the term *isostasy* to denote such condition of static balance in the external portion of the earth.

The earlier and most of the later data upon which the doctrine of isostasy depends were *indirect*, i. e., they were inferences from the characters and relations of formations laid down, or terranes lifted and degraded, during long past eons; yet there is no dearth of *direct* data—i. e., data derived immediately from observation—sustaining the doctrine.

One class of such data is found in the relation between tracts of deposition and earthquakes: If the earthquakes recorded in history are separated into three categories of association, viz: (1) earthquakes associated with volcanoes, (2) earthquakes associated with hot springs, and lines or zones of active orogeny, and (3) great earthquakes apparently not connected with vulcanism or orogeny—it will be found that the greater part of the third category have affected tracts of rapid deposition, and commonly that after the tremor the land stood lower than before. Thus, the Charleston earthquake of 1886, felt over an area of nearly a million square miles, affected the Atlantic coastal plain of the United States, a tract of remarkable simplicity and uniformity of movement during later geologic times yet one of rapid and long continued deposition; the New Madrid earthquake of 1811–13, felt over an area of certainly a million and a half square miles in central and eastern United States, affected a tract of exceptionally gentle movement and uniform geologic history, though the unloading ground of the great river of the continent, and the land was spasmodically depressed over thousands of square miles; the great Lisbon earthquake of 1755 originated in and affected most disastrously the tract upon which the Tagus drops the detritus gathered from a sixth part of the Iberian peninsula; the Kach earthquakes of 1819 and later dates devastated the delta of the mountain-born Indus and left the land some feet or yards lower than before, thus extending the vast watery waste known as the Rann of Kach; the Cachar earthquake of 1869 similarly affected the deposition-tract of the powerful Ganges and Brahma-putra; the deposition-tract of the mud-stained Hwang-ho and the torrential Yang-tse-Kiang are notoriously earthquake ridden—in short, nearly all if not all of the extensive non-volcanic earthquakes recorded in history centered in tracts of rapid deposition. In some cases the data derived from this relation are equivocal; yet they are sometimes apparently trustworthy.

A second class of direct data sustaining the doctrine of isostasy is found in the relation between tracts of deposition and measured subsidence of the land or encroachment of the waters. If the tracts of rapid deposition are separated into three categories of association, viz: (1) deposition tracts within or near the areas of Pleistocene glaciation, (2) deposition tracts

in or near zones of active vulcanism or orogeny, and (3) deposition tracts in generally stable regions far removed from Pleistocene glaciation, vulcanism and orogeny—it will be found that the greater part of the third category are also tracts of rapid subsidence or of rapid encroachment of the waters. The data derived from this relation, which also are sometimes equivocal though often unmistakable, are of two kinds, which may be called respectively *quantitative* and *qualitative;* the first being actual measures, and the second inferences from analogous measured examples and from known geologic processes.

A good example of the first of these kinds of data is the southeastern shore of North sea, which is burdened beneath detritus dropped from the Rhine, Maas and Scheldt, the Weser and the Elbe, and which has been sinking since the beginning of local history; the island of Batavia, inhabited in the days of Tacitus is drowned; Zuydee Zee was formed by an invasion of the waters about the end of the 13th century; again and again towns and villages have been inundated and swept from the face of the earth; broad slices of ill-fated Heligoland are annually devoured by the sea; the Netherland polders (or dike-protected lands) are maintained by artificial embankments which require raising from generation to generation until now cultivated fields lie 7 to 10 meters below tide level; and the artificial embankments could not withstand the force of the waves were they not themselves protected by much larger natural embankments called dunes (analogues of the "keys" of the American coast). The measured rate of sinking along the Netherland coast ranges from 0·09 meter to 0·75 meter per century; since 1732 the mean rate, according to Girard, has been about 0·26 meter per century.* The rate of sea encroachment on the lowlands cannot accurately be determined, by reason of the artificial intervention which permits cultivation of lands lying far below tide level; the rate of encroachment on the higher lands is measured by the destruction of Heligoland, which was 190 or 200 kilometers in circuit in the year 800, 72 kilometers in 1300, only 6·5 kilometers in 1649,† and is decimated annually. Another example is the tract centering about New York bay though extending from Long Island sound to Chesapeake bay, into which is poured nearly all the sediment gathered from a many times larger semi-ellipse in eastern United States, and in which also the sinking is known to be rapid. According to the conservative estimates of the late Dr. George H. Cook, the direct subsidence reaches and probably exceeds two feet per century.

* Recherches sur l'Instabilité des Continents, 1886, p. 168.
† Ibid, p. 31.

The encroachment of the bays and of the adjacent Atlantic is proportionately rapid; within the last fifty years it has reached half a mile in some localities, averaging a furlong or more, and has destroyed property amounting to millions of dollars. Both of these deposition tracts lie near and possibly within the influence of Pleistocene glaciation; yet they are especially significant in that the quantitative data derived from them are connected with and give value to data of the qualitative kind.

Through the association of the two kinds of data on the Netherland and New Jersey coasts, as well as through inference from geologic process, it is found that the most trustworthy physiographic indications of subsidence are: (1) encroachment of the sea; (2) wave-built breakwaters along lowland coasts (the "dunes" of Holland, the "keys" of America); (3) precipitous and talus-free or undercut cliffs along highland coasts; (4) estuaries at the mouths of sediment-bearing rivers; and (5) natural levées along the lower courses of rivers, leaving low-lying and periodically flooded marshes or salines on either hand. These physiographic indications express rates, though only in a qualitative way: Thus, the rate of encroachment is a function of the subsidence, but is affected by the seaward inclination, by the obduracy of the terrane, by the force of the waves and currents, etc. The building of natural breakwaters is characteristic only of coasts skirted by submerged terraces or shelves; for when coasts are so conditioned the waves come in with ever increasing impetus over the subsiding sea bottom, constantly casting up sand to strengthen the barrier, and if the contiguous land is low a lagoon or "sound" is formed behind the barrier and widens more rapidly than the barrier, is driven inland until both are finally overflowed and converted into open sea, when the process is repeated on new-made shores; and thus in a general way the strength of wave-built breakwaters and the width of the lagoons separating them from the mainland give rude measures of subsidence. Talus-free cliffs are indeed an indication of the ever increasing force of the waves on subsiding coasts; yet, while the cliff configuration of subsiding tracts like Chesapeake bay and of rising tracts like Puget sound are markedly distinct, so many other conditions affect sea-washed rock faces that they are useful only in exceptional cases. Again, estuaries may be inherited from earlier eons, and at the best only indicate that subsidence outruns sedimentation, thus giving minimum rather than mean measures of movement. Levée-building, on the other hand, may represent merely diminution in declivity resulting from the pushing out of deltas, and on the whole tends to give excessive or at most maximum measures of subsidence.

The qualitative kind of direct data are well exemplified at the head of the Bay of Bengal with the adjacent Sanderbands, the depositing ground of two of the most potent rivers of the globe (Ganges and Brahmaputra), where the rate of subsidence —shown by the Indian geologists to have reached over 400 feet in recent geologic times—has not been measured, yet is proved to be rapid by the coastal configuration, by the estuaries through which the rivers embouch, and by the immense natural levées flanking the rivers and their distributaries and bounding broad intervening flats, or "jhils"; they are exemplified again at the mouths of the Amazon and la Plata, which together carry the degradation products of the greater part of the South American continent, and which embouch into vast estuaries after dividing into networks of levée-flanked distributaries insulating extensive marshes; they are exemplified also about the mouth of the Indus, once supposed to be an area of uplift but now known to be subsiding, where the larger distributaries are estuarine and where the interstream flats are vast salines annually flooded and silt-mantled by fresh waters, yet always so delicately adjusted to tide level as to be flooded and salt-mantled by sea waters during each annual monsoon; they are apparently well exemplified again about the northern end of Caspian sea and in the delta plains of the Volga and Ural, as well as about Aral sea and in the broader delta plains of its far-reaching affluents; they are exemplified also on the northern and western shores of Black sea, and still more notably about the Sea of Azof, which together receive the drainage of a third of Europe; they are exemplified, particularly the estuaries and anastomosing levée-flanked distributaries, on the western shore of Hwang-hai (China sea or Yellow sea) about the mouths of the muddy rivers draining the eastern Himalayas and the loess-mantled plateaus of eastern Thibet and western China; they are strikingly exemplified at the northwestern extremity of Adriatic sea about the mouth of the levée-lifted Po, perhaps the most energetic river of the world in proportion to its size; and they are exemplified more notably than elsewhere on the globe about the shores of the Gulf of Mexico, the depositing ground of rivers degrading a fourth of the North American continent. These and other notable examples are summarized in the accompanying table, which is graphically depicted in figure 1 (p. 183).

On reviewing these examples yielding direct yet only qualitative data concerning the relation between deposition and subsidence, it appears that the data are of unlike value: The most extensive degradation tract on the globe is that of the Amazon, but the Amazonian detritus is partly spread over a vast flood plain lying at base-level, partly dropped in an exten-

sive estuary, and partly cast into the sea to be widely distributed by exceptionally powerful oceanic currents; and, moreover, this vast river is comparatively little affected by seasonal freshets such as multiply the efficiency of extra-tropical streams.

Principal Degradation Tracts of the World (exclusive of Africa, Australia and Northern Lands) with the Correlative Deposition Tracts.

No.	Degradation Tracts. Rivers.	Areas.	Deposition Tracts. Water Bodies.	Approximate Areas.	Ratio.
		sq. m.			
1	Amazon	2,010,000*	Atlantic	?	?
2	Mississippi, Rio Grande, *et al.*	1,804,737†	Gulf of Mexico (N. half)	sq. m. 277,592‡	6½ : 1
3	Yang-tse-Kiang 730,000; Hwang-ho 715,000	1,445,000*	Hwang-hai (W. pt.)	? 200,000§	7¼ : 1
4	La Plata	1,175,000*	Atlantic	?	?
5	Danube 312,000; Don 225,000; Dnieper 225,000; Dniester 30,000; Other rivers 200,000	992,000*	Black sea, Azof	172,500‖	5⅞ : 1
6	Volga 530,000; Ural 110,000	640,000*	Caspian (N. half)	90,000‖	7 : 1
7	Syr Daria 316,000; Amu Daria 260,000	576,000*	Aral	24,000¶	24 : 1
8	Ganges, Brahmaputra	575,000*	Bay of Bengal (N. part)	? 100,000§	5¾ : 1
9	Indus	415,000*	Arabian gulf (E. part)	? 80,000§	5 : 1
10	St. Lawrence	395,000*	Gulf of St. Lawrence	? 50,000§	8 : 1
11	Rhine 87,000; Elbe 56,000; Weser 17,000; Other rivers 10,000	170,000*	North sea	? 15,000§	11⅓ : 1
12	Connecticut, Hudson, Delaware, Susquehanna, *et al.*	83,000†	Long Island sound, New York bay, Raritan bay, Delaware bay, Chesapeake bay, *et al.*	?5,000†	16½ : 1
13	Po 40,000; Adige, *et al.* 30,000	70,000*	Adriatic (N. part)	? 7,000§	10 : 1

The second degradation area in extent is that of the Mississippi, the Rio Grande, and their weaker neighbors, whose deposits not only fall into the nearly enclosed Gulf of Mexico but, by reason of the prevailing currents, are confined to its northern fraction. A portion of this degradation area is indeed subarid and only a small portion is mountainous; yet in general degradation is rapid—toward the Rocky Mountains because of

* Reduced to statute miles from A. Keith Johnson's "Physical Atlas of Natural Phenomena," 1856, pls. 16, 17.

† Computed by means of the planimeter from the United States Geological Survey "9-sheet" base map of the United States, by John B. Torbert.

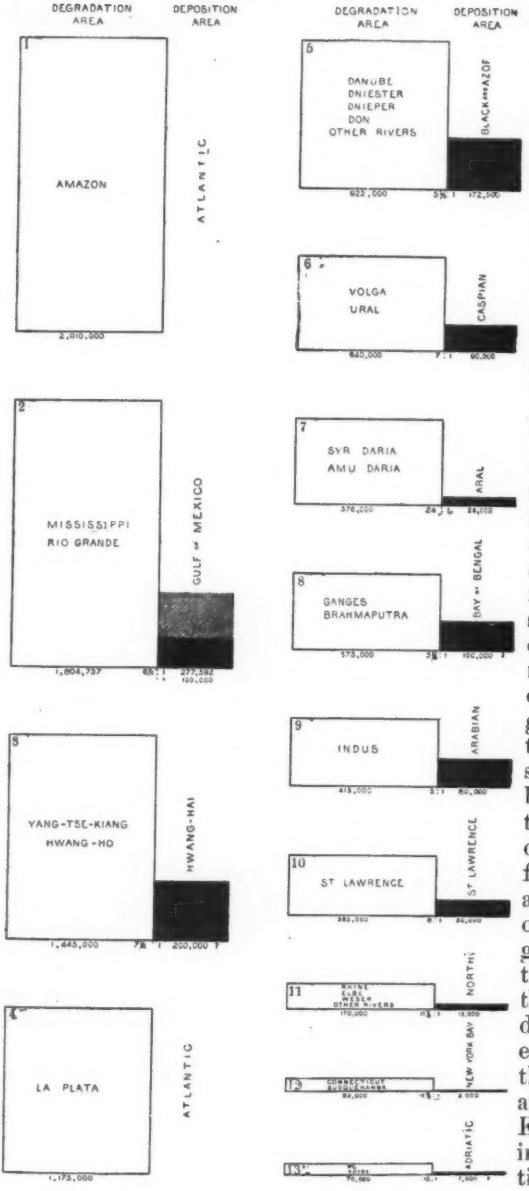
‡ Computed by John B. Torbert.

§ Estimated.

‖ Encyclopedia Brittanica, 9th edition.

¶ Appleton's American Encyclopedia.

1.



high declivity, over the Plains by reason of late Tertiary elevation, in the northern interior because of the easily eroded late Pleistocene drift, in the Cumberland plateau and the western Appalachians by reason of a late Tertiary elevation to which the streams are not yet adjusted, in nearly all parts by reason of seasonal storms or vernal snow-melting; indeed by far the greater part of the area stands so high above base-level that the activity of degradation is fairly comparable with that of the other great tracts of the globe. In the third degradation tract in extent (that of the Hwang-ho and Yang-tse-Kiang) unloading is unquestionably pro-

ceeding rapidly, but the correlative area of loading is so ill-defined as hardly to be susceptible of estimate; while in the fourth area (that of la Plata), where degradation is probably more sluggish, the deposition area is still more indefinite. The fifth in extent of the degradation tracts concentrates its detritus in the well defined area of Black and Azof seas; yet so little is known of the coastal configuration of these seas and of the possible influence of Pleistocene glaciation and contiguous orogeny that the data afforded by this example are of little service. The deposits of the sixth degradation tract are in like manner concentrated upon a limited area which may be assumed to equal the northern half of Caspian sea, and in the seventh tract the concentration is still greater, the degradation tract tributary to the Aral being no less than twenty-four times that of deposition; but both examples are enclosed basins in which the record of isostatic subsidence is complicated by the direct displacement of the water and also by the variations in water-volume depending on climatal conditions, and accordingly the data in these cases are unworthy of trust. The eighth degradation tract (Ganges and Brahmaputra) is especially noteworthy by reason of the activity of the rivers and the vast volume of detritus annually discharged; but the correlative deposition area is so ill defined that, apart from the incomplete measurements of the Indian survey, the relative value of the data afforded by this example is not easily ascertained; and this is true in still stronger measure of the ninth tract, or that of the notably active Indus. The tenth degradation tract in extent (St. Lawrence) is useless as a measure of isostatic subsidence, (1) because it is wholly within the area of Pleistocene glaciation, (2) because the correlative deposition tract is ill-defined, and (3) because its course is interrupted by several settling basins. The eleventh tract (that of the Rhine and its neighbors) is one of activity in both degradation and deposition, and one moreover in which the combined effect of tides and currents probably tends to confine deposition to the comparatively narrow zone along which subsidence is best marked, if not chiefly to Zuyder Zee and the riparian estuaries; yet it is possible if not probable that this area is within the influence of Pleistocene glaciation, and hence of an extraneous disturbance of equilibrium not yet completely restored. The twelfth tract, too (New York and neighboring bays), lies partly within the area of glaciation, and is moreover affected by a modern displacement; but it acquires value from the connection with rude yet useful rate measurements. The smallest of the degradation tracts (that of the Po, the Adige, the Piave, and several smaller streams, all of great activity), concentrates its products in a presumptively

limited portion of Adriatic Sea; yet the value of this example is diminished by reason of the vulcanism and orogeny of contiguous territory. For similar reasons and because of its irregularity of outline and inequality of loading in different parts, the Mediterranean may be excluded from the list of noteworthy deposition tracts of the globe. The African and Australian degradation tracts may also be neglected, partly because the areas are ill determined, partly because deposition is seldom concentrated in measureable tracts.

Weighing the various considerations affecting the value of the data yielded by each of the tabulated deposition tracts, they appear to fall into the following order: (1) Gulf of Mexico, (2) North sea, (3) New York bay, (4) Bay of Bengal, (5) Adriatic sea, (6) Hwang-hai, (7) Black and Azof seas, (8) Arabian Gulf, (9) the Amazon estuary, (10) la Plata estuary, (11) Caspian sea, (12) the Aral, and (13) Gulf of St. Lawrence. On reviewing the data yielded by the several examples in view of this weighing, in view of the ratios between areas of degradation and areas of deposition, and in view of the relative activity of the several rivers, the influence of tides and currents, etc., it appears that all are consistent—that every considerable deposition tract beyond the reach of Pleistocene glaciation, vulcanism, and orogeny is subsiding; that, other things equal and so far as the data are available and trustworthy, the rate of subsidence is proportional to the relative areas of degradation and deposition; and that, other things equal and so far as the data are available and trustworthy, the subsidence is proportional to the activity of the rivers in the correlative degradation tracts.

So the indirect data concerning isostasy, derived through inferences from formations deposited or terranes degraded during long past cons, are supplemented by a trustworthy body of direct data derived from the physiography of the earth in its present condition; and the direct data are superior to most* of the indirect in that they are susceptible of relative, and in some cases absolute, evaluation.

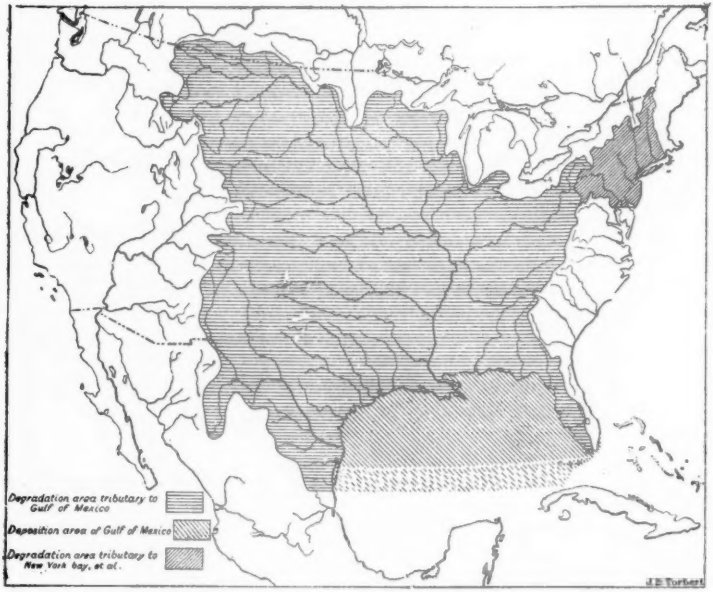
II.

Even on casual inspection it is apparent that the Gulf of Mexico is one of the most fortunately situated deposition tracts of the globe for the measurement of isostatic subsidence; for it is a land-rimmed basin of considerable area, connected with open sea through relatively narrow straits, and fed by drainage

* In one case the indirect data have been evaluated. This is Gilbert's classic study of the strength of the earth's crust as indicated by the deformed shore lines of the extinct Lake Bonneville (Bull. Geol. Soc. Am., vol. i, 1889. pp. 23-27; Monograph I, U. S. Geol. Survey, "Lake Bonneville," 1890, p. 387, et seq.).

from a many times larger degradation tract (figure 2). On closer inspection the first impression is strengthened: The northern half of the Gulf with the adjacent lands (of which alone the geologic history has been clearly read) is a province of simple structure, of limited and uniform continental movements since the middle Cretaceous; furthermore, it is this northern half of the Gulf which receives the drainage from the second largest degradation tract of the globe; moreover, one of the strongest oceanic currents of the globe—the main Atlantic equatorial current—enters the Gulf through Yucatan

2.


Degradation area tributary to Gulf of Mexico
Deposition area of Gulf of Mexico
Degradation area tributary to New York bay, et al.
J.E. Torbert

channel and sweeps through the basin in such fashion as to concentrate the sediments upon a narrow zone skirting the northern border of the basin; and finally the influence of sedimentation is not confined to a single delta but is so distributed that the rate of deposition is variable in different parts of the littoral zone, though in simple and easily ascertained fashion.

Unfortunately the Gulf coast has only recently been surveyed with precision, and the surveys have not yet been repeated in such manner as to give quantitatively exact measurements of land-subsidence or sea-encroachment; but the

physiographic indications of land-subsidence are numerous, consistent, and unmistakeable. Thus, island after island along the Louisiana coast has been submerged bodily or devoured by slices, and many historic plantations on the shores of Mississippi sound and the open Gulf have melted into the waters within the present century; thus, too, the coasts (with one or two most significant exceptions) are skirted by wave-built breakwaters separated from the mainland by long narrow bays (the "keys" and "sounds" of the vernacular) from the Rio Grande to Florida strait; again, wherever the generally low coastward lands rise a dozen feet or yards above tide, they are carved into precipitous talus-free cliffs; half of the rivers, too, albeit heavily detritus-charged, embouch into estuaries; and, moreover, each principal river, whether estuarine or delta-building toward its mouth, divides into distributaries (or "bayous") in its lower reaches, and the anastomosing channels are flanked by natural levées separating periodically-inundated flats, which are lakes, marshes, salines, or "black prairies" according to local conditions. In addition to these physiographic data there are found buried forests, old causeways now overflowed at low tide, aboriginal shell heaps nearly or quite submerged, savanna pine forests once luxuriant but now poisoned by salt water, and various other indications of changing relation between land and sea; and it is to be observed that while these indications vary in strength they are all consistent in direction—all point to subsiding land, none point to rising or even stationary land.

On comparing the physiographic data about the shores of the Gulf with the like data yielded by measured examples of New Jersey and the Netherlands, it would appear, (1) that the average rate of sea-encroachment about the Gulf is nearly or quite as high as on the New Jersey coast and higher than on the Netherland coast, at least since the building of the dikes; (2) that on the average the wave-built breakwaters are higher and more distant from the mainland than in New Jersey, and more extensive than, though scarcely so high and distant as in the Netherlands; (3) that the talus-free cliffs are even more characteristic than in New Jersey or (probably) the Netherlands; (4) that on the average the estuaries are nearly as broad and deep as in New Jersey and more extensive than in Holland: and (5) that the natural levées are relatively higher and broader than in New Jersey and, so far as comparison is possible, about as high and broad as in the Netherlands. The value of the physiographic indications of subsidence of course depends largely on a number of local and general conditions, such as volumes of rivers, height of tides, strength of oceanic currents, direction of prevailing winds, the material, height, and

general configuration of shores, the breadth and depth of the water-body in which the waves are generated, etc.; yet howsoever these conditions affecting the comparison are weighed, the Gulf phenomena appear to record an average subsidence fully as rapid as that of the Netherlands or New Jersey; or (the vertical movement in the carefully measured case amounting to 0·26 meter and in the more roughly measured example reaching two feet per century) of at least a foot in a hundred years.

On comparing this value with the rates of degradation and correlative deposition, a relation is obtained which, although lacking in precision, is nevertheless useful: The area of degradation is 1,800,000 square miles; the maximum assignable area of deposition is less than 300,000 square miles, and since the direction and force of currents and the configuration of the Gulf bottom alike indicate that appreciable sedimentation must be confined to a relatively narrow zone skirting the coast, it may be placed at a third of that area or 100,000 square miles, which is one-eighteenth that of degradation. Now, the commonly accepted rate of degradation of the earth's surface, based on the surveys of the Mississippi by Humphreys and Abbot, is a foot in 6000 years; and this corresponds to deposition within the Gulf reaching one foot in 333 years. So it would appear that the average rate of subsidence deduced from comparisons with New Jersey and the Netherlands is three times higher than would be required for isostatic adjustment; and although the various factors are so uncertain (probably Humphrey's and Abbot's value and the deduced rate of subsidence are too low and the assumed deposition area too high) that the estimate is subject to a "probable error" perhaps large enough to explain the discrepancy, the discrepancy nevertheless suggests that a part of the subsidence may be due to some other cause. This suggestion derives strength from the indications of general subsidence along the contiguous Atlantic coast of the United States.

On comparing the local physiographic indications of subsidence at various points on the Gulf coast, a noteworthy diversity is found. Thus, the most decisive historical records of encroachment come from the Louisiana and Mississippi coasts, and there, too, talus-free cliffs are most characteristic. Again the strength of keys and the width of sounds varies widely; along the Florida coast, despite the long sweep of storm winds and trades, the keys are weak, the sounds narrow and shoal; toward the Appalachicola and Mobile bay the keys strengthen and the sounds widen, save where dammed by deltas; west of Mobile bay the keys are huge but half submerged banks rising in a line of islands separated from the mainland by the broad Mis-

sissippi sound; west of the great delta the corresponding keys are completely submerged and reduced to a series of banks and shoals separated from the mainland by a trough even broader than Mississippi sound, and new keys and sounds are forming along the present coast; southwest of Galveston bay the keys are of unparalleled strength and continuity, while the sounds are broad and scores or even hundreds of miles in length. Moreover, some rivers are estuarine while others are delta-builders, and this difference in habit is evidently independent in large measure of stream-volume and of sediment. Yet on careful examination, the apparent discordance falls into harmony: The strength of keys and width of sounds is least in the eastern part of the embayment where the sediment-bearing rivers are relatively short and feeble, greater in the northwest where the rivers are longer and more potent, and greatest about the depositing ground of the chief river of the continent. So, too, all the large rivers of the western and eastern coasts are delta-builders; while all of the extra-Mississippi streams within a hundred or a hundred and fifty miles of the great river (and presumptively within reach of its isostatic influence) embouche into estuaries.* This harmony is suggestive, if not precisely indicative, of a quantitative relation between local deposition and local subsidence.

Summarily, the Gulf of Mexico, considered as a unit, is one of the most fortunately situated deposition-tracts of the world for yielding a measure of isostatic subsidence; considered again as a unit, its shores appear to be subsiding quite as rapidly as isostasy demands; and considered as an assemblage of deposition sub-tracts, the varying rates of subsidence appear to be delicately adjusted to the local rates of deposition.

So the data relating to the condition of the earth's crust derived from the modern Gulf of Mexico indicate that throughout the vast geologic province of southeastern North America, isostasy is probably perfect, i. e., that land and sea bottom are here in a state of hydrostatic equilibrium so delicately adjusted that any transfer of load produces a quantitatively equivalent deformation.†

* These features are set forth at some length in a paper on the Lafayette formation, 12th Ann. Rep. U. S. Geol. Survey, 1892, pp. 347–521, pls. xxxii–xli.

† Thomson and other physicists concluded some years ago, after a study of the tides, precession, etc., that the earth as a whole must be as rigid at least as steel. Newcomb has quite recently concluded, after discussing new data (including Chandler's brilliant coördination of the recorded variations in latitude in connection with Oppolzer's computations), that "the earth yields slightly less . . . than it would if it had the rigidity of steel, and that it is consequently slightly more rigid than steel" (Monthly Notices of the Royal Astronomical Society, vol. lii, no. 5 (1892), p. 339); so that while Thomson's result gives a minimum value, that of Newcomb gives a maximum value for the rigidity of the earth as determined from cosmic relations. Now, without analysis of the differences in defini-

III.

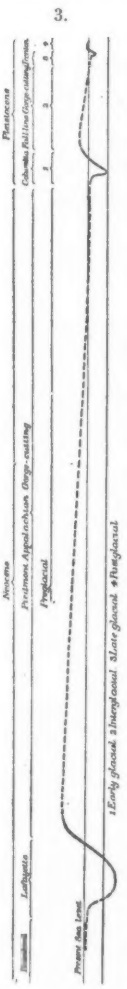
The measure of isostasy found in the modern Gulf of Mexico might be tested by comparison with the measures yielded by other gulfs and bays, were the data concerning the several fortunately situated deposition-tracts sufficiently precise; but in the dearth of surveys and bench-marks it must suffice to repeat that the physiographic data afforded by the Bay of Bengal, the Adriatic, Hwang-hai, Black and Azof seas, the Arabian gulf, the mouths of the Amazon and la Plata, etc., are harmonious therewith. The measure cannot well be tested by comparison with the indirect data derived from study of ancient formations or terranes in other geologic provinces, since most of such data are isolated and, by reason of ignorance concerning the absolute or relative areas of the tracts of degradation and deposition respectively only rudely qualitative, and since in the single case in which the indirect measure is quantitative—Gilbert's ancient Lake Bonneville—the problem is so complex as to permit only the statement that the results are in a general way harmonious with the data yielded by the modern Gulf. The measure may, however, be checked by comparison with past records of the geologic province represented by the Gulf and adjacent lands.

The later geologic history of the Gulf of Mexico is now fairly well known. The uppermost structural unit of the contiguous land area is the early Pleistocene Columbia formation; the next in age is the late Neocene (probably Pliocene) Lafayette (Appomattox) formation. Now the history recorded in these formations and in the unconformities by which they are bounded may be thus interpreted: Before the Lafayette period the configuration of the southeastern quarter of the continent was much the same as to-day, save that the land lay somewhat lower and flatter; then came the Lafayette inundation, 300 to 900 feet in depth and extending from 100 to 500 miles inland; this was followed by a high level period during which the land was tilted seaward from the Appalachian axis but lifted 300 to 1000 feet higher than before (or now), and during which half of the volume of the Lafayette formation was degraded, while the rivers carved broad and deep canyons forming the estuaries yet indenting the Atlantic and Gulf coasts; next the land gradually subsided to its previous (and about the present) mean

tion of terms to which are due the apparent discordance between the current doctrine of physics and that of geology, it may be pointed out that these remarkable and admirable inductions of physics have no more to do with the deformation dealt with by geologists than laboratory experiments on the rigidity and brittleness of ice have to do with the movements of glaciers; and the mobility of the terrestrial crust through a range reaching thousands of feet and even miles is now quite as well established as is the mobility of glacier ice.

altitude, though the relative lifting of the Appalachian axis persisted; then came the Columbia inundation, which was coeval with the first known ice-invasion, during which the Atlantic and Gulf again united and flowed inland 20 to 500 miles, rising 100 to 700 feet above their present level; finally the land rose so high as to permit the excavation of the submarine channels of the Hudson, the Delaware, the Susquehanna, the Potomac and the Mississippi, but soon subsided; and this last subsidence of the southern land seems to have been little affected by the later ice invasions, and is perhaps, even probably, yet in progress. These oscillations are represented graphically in the accompanying diagram (figure 3) in which the ordinates represent time, the abscissas continental altitude.*

3.



On comparing, or rather contrasting, these great continental oscillations with the gentle modern movement along the shores of the Gulf, they are found to differ widely: The modern subsidence appears to be a gentle warping in such direction as to deepen the basin and gradually submerge its perimeter; the old oscillations were widespread and involved both sea bottom and continent. The modern movement is slight and commensurate with the simple and uniform processes of degradation and sedimentation; the old movements were cataclysmic, and utterly transcended the influence of rain and rivers—they were indeed of greater amplitude than any other continent movements of southeastern North America since the close of the Cretaceous.

Now the modern movements not only yield a quantitative measure of isostacy (with a "probable error" whose value is indeterminate) but give a rude measure of the efficiency of degradational transfer of matter on the surface of the earth's crust in producing deformation; while the movements recorded in the Columbia and Lafayette formations were of so much greater amplitude that they may not be referred to a similar cause. In this province as in others, therefore, it becomes necessary to discriminate the two classes of earth movements elsewhere called,

* They are represented physiographically in a series of tectonic maps illustrating a paper on the Lafayette formation now in press as a part of the 12th Ann. Rep. U. S. Geol. Survey (pls. xxxix–xli).

respectively, *antecedent* and *consequent*—the first including those grand initial movements of debatable cause by which continents are lifted and sometimes deformed or drowned, and the second including the more restricted movements due to loading and unloading.

So the modern province measures the competence of isostasy, the ancient province its incompetence; the modern Gulf illustrates the magnitude, the ancient Gulf the minitude, of isostatic deformation as a means in continent making.

IV.

Recurring now to the direct and indirect measures of isostasy afforded by the Gulf of Mexico in its present condition and past history, it may confidently be concluded: (1) that the direct data of modern times indicate that deposition and isostatic subsidence are not only related sequentially but that under favorable conditions they are quantitatively equal or sub-equal; (2) that this measure of isostasy is consistent with the direct data, both quantitative and qualitative, yielded by other noteworthy deposition tracts of the globe; and (3) that the indirect data afforded by the Gulf indicate that isostatic (or consequent) movement alone is incompetent to explain the general continental oscillations recorded in the Neozoic deposits. Thus the Gulf of Mexico yields both maximum and minimum measures of isostasy.

Art. XXVI.—*Persistence of Vision;* by Ervin S. Ferry.

[Contributions from the Physical Laboratory of Cornell University, No. 10.]

Ever since the time of Aristotle, it has been known that when the eye is impressed by light, the sensation persists even after the exciting cause has ceased to act. In his work on dreams, Aristotle describes duration of impressions in the retina and then deduces as the cause of dreams a similar persistence of impression on the sensorium of things experienced when awake. The ancients noticed and correctly explained many optical illusions by persistence of vision; but it was not till twenty centuries after Aristotle that anyone attempted to measure the duration of visual impression. Segner* measured the duration of the light impression from a spark of a rotating stick and adopted 0·1 second as the probable value. D'Arcy,†

* De raritate luminis (Göttingen, 1740. pp. 5–8).
† Mémoire sur la durée de la sensation de la vue (1768).

Cavallo,* and Parrott† have since fully substantiated this value by accurate measurements. Plateau,‡ in 1829, found that when discs divided into sectors alternately black and of some special color were rotated, different speeds were required to produce uniformity of tint, depending upon the color of the pigment used to paint the alternate sectors. By noting the angular size of the black and the colored sectors and the speed just necessary to produce uniformity of tint, he was enabled to determine the absolute duration of the maximum impression for the different colors experimented upon. By using the different discs painted in sectors, each having black alternating with some one color, Plateau obtained the following values for the duration of impression for these particular colors:—

White	0·191 secs.
Yellow	0·199 "
Red	0·232 "
Blue	0·295 "

One great difficulty with this method is that since no pigment gives a pure color and since pigments vary so widely in tint, the results obtained hold only for the particular specimens experimented upon. To overcome this difficulty, Dr. E. L. Nichols§ employed a revolving disc having sectors cut out, in front of the slit of the spectroscope, and defined his colors by their wave-lengths. In this manner by suitably choosing the wave-lengths used for observation, a curve was drawn showing the relation between the duration of impression and the color corresponding to any wave-length.

From the results obtained by Plateau, Emsmann,‖ Nichols and others, it was reasoned that the duration of retinal impressions depends upon the intensity of the light-giving source and upon the color of the light entering the eye. To test the validity of this latter proposition, and to determine the principal factors producing persistence of vision has been the object of the series of experiments now to be described.

Apparatus and Method of Observation.

The plan of the investigation was to obtain curves showing the relation between duration of the retinal impression of the normal eye and wave-length of light observed for spectra of

* The elements of natural or experimental philosophy (London, 1803), vol. iii, p. 135.

† Entretiéns sur la physique (Dorpat, 1819), vol. iii, p. 235.

‡ Dissertation sur quelques propriétés des impressions produites par la lumière sur l'organs de la vue. (Liege, 1829).

§ On the Duration of Color Impressions upon the Retina, this Journal, vol. xxviii, p. 243.

‖ Ueber die Dauer des Lichteindrucks, Pogg. Ann., xci (1854), p. 611.

different intensities; to compare these curves with another showing the distribution of luminosity in the spectrum used; and finally to compare similar curves obtained from dichroic eyes.

The apparatus for the measurement of the retinal impression consisted of a diffraction-grating spectrometer; a sectored disc that could be revolved by an electric motor, interposed between the lamp and collimator; and a chronograph to register accurately the number of revolutions of the disc. The source of light was a hundred-volt Edison incandescent lamp supplied by a secondary battery, and it was kept at constant candle power by varying the resistance in circuit so that a volt-meter would always indicate one hundred volts. In front of the lamp was mounted a large condensing lens for the purpose of projecting upon the collimator slit an enlarged image of the filament. In this way a uniform distribution of light was obtained in all parts of the field of the spectrometer. At the focus of the eye-piece of the telescope was placed a diaphragm so as to isolate from the spectrum the single color it was desired to observe. The disc had a ninety-degree sector cut out from each end of a diameter so that when the disc revolved there would be seen in the telescope equal periods of illumination and of darkness. The speed of the disc was controlled by means of a friction-brake managed by the observer. On the shaft of the disc was mounted a contact device by means of which an electric circuit was made for an instant on each revolution of the disc. This current was conducted to the primary of an induction coil having the secondary so connected to a chronograph cylinder that a spark would puncture a blackened paper on the cylinder every time the sectored disc revolved. Pressing against the chronograph cylinder was a stylus electrically connected to the escapement of a standard clock. By this device the number of revolutions of the sectored disc in a second could be very accurately determined.

When taking an observation, the experimenter sits at the telescope of the spectrometer with one hand on the brake regulating the speed of the sectored disc. The disc is first made to revolve so slowly that the field of view in the telescope flickers, and then the speed is gradually increased till the point is reached when the field just becomes quiet; then a key is pressed and an assistant rotates the chronograph cylinder for five seconds and takes the record of the speed of the sectored disc. This gives the duration of the maximum impression on the retina. Such a short time of observation as here used has many manifest advantages. Even when the disc is steadied by a heavy fly-wheel as was done in these experiments, and rotated by a powerful motor, the speed can be kept constant for only a short time. Other experimenters have taken one-

minute observations or longer, and found their separate observations differing by a large per cent from the mean. With this apparatus a difference of more than three per cent between two observations of the same region in a spectrum of ordinary brightness is rare. The observations at regions of low brightness are more difficult.

The eye was subjected to the intermittent light for as short a time as possible so as to avoid the secondary colors described by Signor Cintolesi.* After each observation on colored light the eye was rested by looking at white light and the succeeding observation was invariably made on a different color. Thus the disproportionate increase of sensitiveness of the eye for more refrangible rays due to adaptation, as noticed by M. H. Parinaud,† was guarded against. These observations were made in a room with blackened walls and every attempt was made to exclude extraneous light. It was also soon found that precautions were necessary to eliminate the slight tremor produced by the motor and the disc, because a vibration of the lamp or of the diffraction-grating produces a flicker in the field of view that cannot be distinguished from the appearance produced by a too slow rotation of the sectored disc.

Duration of Light Impressions on the Normal Retina.

To represent the normal eye, three persons were selected of about the same age, whose eyes were free from Daltonism, astigmatism, near- and far-sightedness and from such abnormal color sensations as have been recently observed by Captain Abney‡ in confirmed users of narcotics and stimulants. How very closely the duration of retinal impression for each part of the spectrum agreed for these cases is shown in the following table:

TABLE I.

Wave-length.	Duration of retinal impression in seconds.		
λ	E. S. F.	G. W. B.	E. F. N.
·435	·0357	·0357	·0333
·480	·0250	·0263	
·510	·0200	·0186	·0200
·540	·0156	·0152	
·570	·0139	·0139	·0139
·589	·0132	·0128	·0128
·615	·0141	·0142	
·645	·0156	·0152	
·684	·0192	·0179	·0192

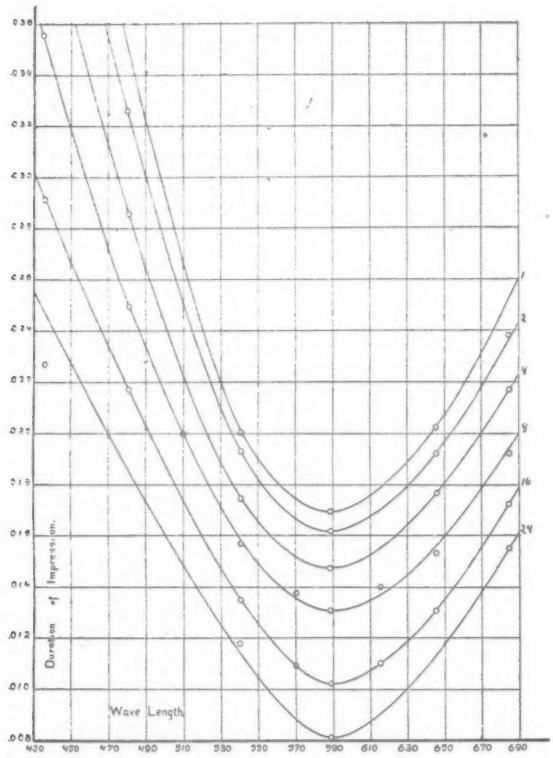
* Ann. di Optalmol. II and III, 1879.

† De l'intensité lumineuse des couleurs spectrales, Comptes Rendus, xcix, p. 937.

‡ On the Examination for Color of cases of Tobacco Scotoma, and of Abnormal Color-blindness, Roy. Soc. Proc., xlix (1891), p. 491.

The values given in this table as well as in all the succeeding tables are not averages of a number of observations, but are the values of a single set of readings. The third and fourth columns are the values obtained by two observers who had only used the apparatus for about an hour, and are hence less reliable than the values in the second column which have been many times repeated. The curve platted from the values in the second column is shown in fig. 1, curve 8.

1.



Duration of Impression of normal eye for different colors and different intensities.

The fact was noticed with some surprise that on different days the observations were nearly identical, if the eyes had not been strained or made more than normally sensitive by re-

maining for a long time in a dark room. And it was also found that the sensitiveness of the eye might have changed by several per cent without producing any noticeable difference in the duration of the retinal impression. This shows two things: first, that the personal equation, or more properly the personal error, in this sort of investigation is less formidable than ordinarily supposed; and secondly that a comparatively large change of sensitiveness of the eye is required to produce a marked change in the duration of the retinal impression.

An examination of this curve (8, fig. 1) shows that the retinal persistence is very different for different parts of the spectrum. As in the curves published by Dr. Nichols, in the paper already cited, the minimum duration is near the D line, and from this point the duration steadily increases toward each end of the spectrum. The observations were carried relatively farther into the blue than in the red, which largely accounts for the apparent unsymmetrical form of the curve. The curve is of the general form of a parabola with its apex approximately at the D line and the two branches becoming parallel to the ordinates of the ends of the spectrum.

Duration of Retinal Impression for light of different Intensities.

In the early part of this century Plateau* noticed that there was an intimate connection between duration of retinal impressions and the intensity of the light producing them. One of the principal objects of this investigation was to determine the law connecting these quantities. To do this, values of duration of retinal impression were obtained for monochromatic light of different intensities. The light intensity was varied by changing the width of the collimator slit according to Vierordt's method. The plan followed was to obtain a spectrum of a certain brightness, and measure the duration of retinal impression at sufficient points in it to be able to plat a curve showing the relation between the retinal persistence and wave-length. Then changing the width of the collimator slit by a definite amount, so as to obtain a spectrum of a brightness in known proportion to that of the preceding spectrum, to determine the duration of impression for the same points as before. In this way the following values were obtained for the duration of retinal impression of monochromatic light of different color and different intensity.

* Dissertation sur quelque propriétés des impressions produites par la lumière sur l'organs de la vue. (Liege 1829.)

TABLE II.

Duration of retinal impressions for monochromatic light of different wave-length, of relative brightness from 1 to 24.

Wave-length.	Duration of retinal impressions in seconds. 1.	2.	4.	8.	16.	24.
·435				·0357	·0294	·0227
·480		·0328	·0286	·0250	·0217	
·510				·0200		
·540	·0200	·0192	·0172	·0156	·0133	·0119
·570				·0139	·0109	
·589	·0170	·0161	·0147	·0132	·0102	·0081
·615				·0141	·0111	
·645	·0204	·0192	·0179	·0156	·0130	
·684		·0238	·0217	·0192	·0172	·0156

These values are platted in the curves shown in fig. 1. The numbers affixed to the curves indicate the relative brightness of the spectra.

These curves show that with increased brightness the values of retinal presistence do not shift their positions relative to wave-length; that as the brightness of the spectrum increases, the duration becomes less in such a manner that each point in the curve is shifted downward by a nearly constant amount; and that the distance separating the different curves has a definite relation to the difference of the light intensity of the spectra from which the curves were obtained.

If the values be noticed for the duration of impression of all the curves, corresponding to any single wave-length, it will be perceived that the following statement is approximately true: as the intensity of light increases in geometrical ratio, the duration of the corresponding retinal impression decreases in arithmetical ratio. This statement can be concisely expressed in the form of the approximate empirical law—the difference of the duration of two retinal impressions produced by two lights of the same color, is inversely proportional to the logarithm of the quotient of the respective luminous intensities.

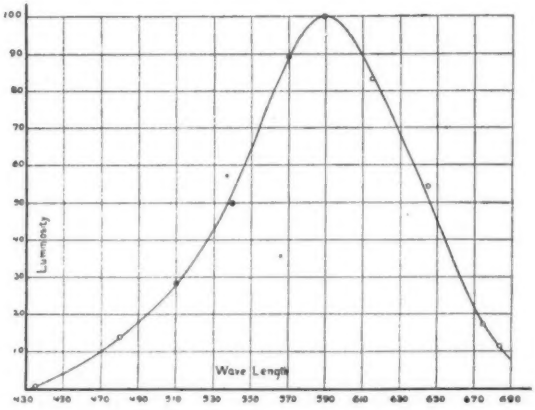
The value obtained for the ends of the spectrum deviate from this law, but this is probably due to the uncertainty of the observations in these faintly illuminated regions. The relation between duration and light intensity, thus far deals simply with lights of the same color. The next object of the experiment was to test the generality of this law, by determining if it would hold for lights of different color.

Relation between Luminosity and Duration of Retinal Impression.

By luminosity is meant the physiological effect of light upon the eye by means of which vision is accomplished. The meas-

ure of luminosity is the amount of light necessary to enable one to clearly distinguish objects. The spectra of various light sources are so very different in the distribution of luminosity, that it was considered necessary to determine these values for the particular lamp used in these experiments.

2.



Distribution of Luminosity in 16-candle power, 100-volt Edison Incandescent Lamp

The method employed was to insert an object into the eye piece of the spectrometer and to reduce the aperture of the objective of the observing telescope by means of a fine micrometer slit till the object was just visible. The reciprocals of the micrometer slit areas gave the relative luminosities of the different parts of the spectrum. This method is less convenient and possibly less accurate than the Rumford photometer method used by Abney and Festing* but it gave a probable error of only about five per cent.

TABLE III.

Distribution of Luminosity in normal spectrum of a 16 C. P. 100 volt Edison Incandescent lamp—Platted in Fig. 2.

Wave-length.	Relative luminosity.	Wave-length.	Relative luminosity.
·435	1·86	·589	100·00
·455	3·06	·615	83·25
·480	13·89	·645	54·37
·510	28·28	·675	17·12
·540	50·00	·684	11·16
·570	89·25		

* Colour Photometry, Trans. Roy. Soc. Lond., 1888, p. 547.

The form of this curve suggested the possibility of luminosity bearing a reciprocal relation to duration of impression. This idea was tested in two ways. First, one particular region in the spectrum was chosen and its luminosity varied so as to be equal to the luminosity of different parts of the normal spectrum as given in Table III; the duration of retinal impression was then measured for these luminosities and gave the following values:

TABLE IV.

Duration of impression for a single color having its luminosity varied so as to equal the luminosities of different parts of the normal spectrum.

Relative luminosity.	Corresponding to wave-length.	Given duration of impression in seconds.
1·86	·435	·0333
13·89	·480	·0227
28·28	·510	·0200
50·00	·540	·0161
89·25	·570	·0143
100·00	·589	·0138
83·25	·615	·0143
54·37	·645	·0161
11·16	·684	·0192

The luminosities taken in this table are the same as in the normal spectrum that gave the values in the fifth column, Table II. A comparison of the third column, Table IV, and the fifth column, Table II, indicates that luminosity is the important factor in persistence of vision. To farther test this deduction, observations were made on the duration of impression for different colors of the normal spectrum, when each color was brought to the same luminosity. If the above deduction is valid, then if each color is brought to the same absolute luminosity, the retinal persistence of each color will give the same value. The values obtained are given below.

TABLE V.

Duration of impression when each spectral color is brought to the same luminosity.

Wave-length.	Duration in seconds.
·510	·0151
·540	·0147
·570	·0149
·589	·0147
·615	·0147
·645	·0147

Duration of Light Impressions on Color-Blind Eyes.

As a still farther test of the theory that retinal persistence is practically independent of color but depends principally

upon luminosity, duration of impression curves were obtained from dichroic eyes. It is well known that a color-blind person not only lacks one of the fundamental color sensations but also that he perceives other colors differently from the normal. For instance, according to Holmgren,* in the spectrum as seen by red-blind persons yellow begins at about line C and extends an orange, yellow and yellowish green and ends near F. At this neutral zone the blue begins and extends to the end of the normal spectrum. If now duration of retinal impression does depend in any way upon color, one would expect that the curves obtained from color-blind persons would differ from those of the normal in a way that could not be explained by considerations of luminosity alone. An examination of about two hundred members of a large class in physics, by Holmgren's worsted method furnished eight cases of color-blindness, one being red-blind, the remainder being green-blind. The proportion of color-blind in even this limited number was about the same as found by Dr. Jeffries† from the examination of 175,000 persons.

These color-blind students were examined for the neutral point by the method of A. Koenig‡ which consists in determining the color that they will match with white or gray. A prism having one face coated with magnesium white was so mounted in the Helmholtz color-mixing spectroscope, that a ray of light from the collimator passing through the prism would be dispersed into a spectrum, while a ray from a second source falling on the white surface would be reflected directly into the telescope. If now the eye-piece of the telescope be removed, one-half the field of view will be filled with color and the other half with pure white or gray. With this arrangement a color-blind person will very accurately set the instrument to the exact point where the two halves of the field of view appear of exactly the same color to him.

After their neutral points had been found in this manner, these gentlemen very kindly offered to spend the time necessary to obtain curves for their retinal persistence.

Mr. W. C. W. is a marked case of inherited blindness to red. His father, uncles and brothers are similarly affected. The red end of his spectrum ends at about ·688 λ, and his neutral point is at ·510 λ. His eyes are otherwise normal.

Mr. H. S. has inherited green-blindness from his *maternal* relatives. Daltonism is so very rare among women that his case was studied with great interest. He is making a specialty

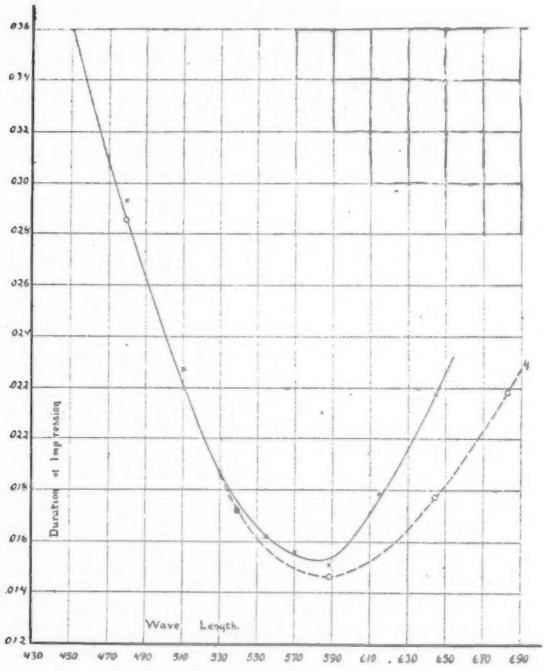
* How do the color-blind see the different colors? Proc. Roy. Soc. Lond., xxxi (1880), p. 302.

† 3·95 per cent among males. "Color Blindness: its dangers and detection." (Boston: 1879.)

‡ Zur Kentniss dichromatischer Farbensysteme. Wied. Ann., xxii (1884), p. 567.

of botany and finds no great inconvenience in any of his studies except chemistry. This subject he was obliged to discontinue as he could not distinguish the characteristic colors of the reactions. His neutral point was sharply located at ·516 λ. This gentleman wore glasses for near-sightedness.

3.



Duration of Impression for different colors of red-blind Eye.

The other observers were not aware of any similar cases in their families. The neutral point of Mr. G. A. W. was located at ·517 λ; Mr. W. M. at ·5165 λ; Mr. L. M. W. at ·518 λ; Mr. H. C. H. at ·516 λ. They are all green-blind and their eyes appear to be otherwise perfect with the exception of Mr. W. M., who is near-sighted. Their values of duration of impression are given in the annexed table.

The values of Mr. W. C. W. are platted in the full curve fig. 3; the broken curve being the curve of the normal eye for the same brightness of spectrum. The values obtained by Messrs. W. M., H. C. H., and L. M. W. are platted in the

curves in fig. 4. The normal curves are drawn in as before to show the relation between the normal and color-blind eyes for persistence of vision.

TABLE VI.

Duration of Retinal Impression for Dichroic Eyes.

(The numbers at the head of each column indicate the brightness of the spectrum.)

	Duration of Impression in Seconds.					
	Red Blind.	Green Blind.				
Wave-length.	Mr. W. C. W.	Mr. H. S.	Mr. G. A. W.	Mr. W. M.	Mr. H. C. H.	Mr. L. M. W.
λ.	4.	8.	4.	2.	4.	8.
·435	----	----	----	·0357	----	·0357
·480	·0294	·0357	·0278	·0333	·0294	·0250
·510	·0227	·0227	·0227	·0263	·0217	·0192
·525	----	·0208	·0200	·0238	·0208	·0185
·540	·0172	·0200	·0185	·0222	·0200	·0172
·555	·0161	·0175	·0179	·0208	·0193	·0156
·570	·0156	·0161	·0161	·0192	·0166	·0143
·589	·0152	·0143	·0152	·0159	·0151	·0125
·615	·0179	·0154	·0156	·0175	·0161	·0143
·645	·0217	·0175	·0167	·0192	·0172	·0156
·684	----	·0210	·0227	·0238	·0217	·0179

These curves show that light impressions of red last much longer on the retina of red-blind persons than on the normal, yellow somewhat longer than normal and the other colors about the same as normal. With green-blind persons, however, green impressions persist much longer than normal, red a little less than normal and the other colors the same as normal.

An explanation of the difference between the duration curves of dichroic and normal eyes was found in the difference in the sensitiveness for different colors of the dichroic from the normal eye. Messrs. Macé and Nicati* from the examination of a number of dichroic eyes obtained luminosity values which indicate, first, that red-blind people perceive red weakly, yellow nearly normal, green better than normal; second, that the green blind have better perception than normal for red, green feeble, yellow and blue normal. A later determination by Abney and Festing† confirmed their conclusions. In this experiment luminosity values were also obtained from Mr. W. C. W. which agree with the two determinations just cited. This shows that if account be taken of the difference between the sensitiveness of the normal and the dichroic eye for different

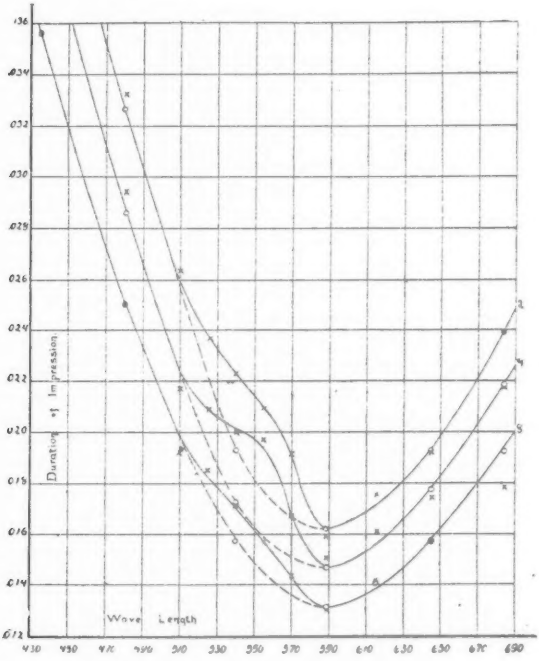
* De la distribution de la lumière dans le spectre solaire (spectre des Daltoniens). Comptes Rendus, xci, p. 1078.

† Colour Photometry. Trans. Roy. Soc. Lond., 1888, p. 547.

regions of the spectrum, that the curves of retinal persistence of the dichroic and the normal eye will be of the same form.

This appears to make the evidence conclusive that color is at most a slight factor in retinal persistence, and that luminosity is the all-important function.

4.



Duration of Impression of Green-blind Eye.

The law previously derived connecting duration of impression and luminosity of lights of the same color can now be made general and independent of color. This approximate empirical law can now be expressed in the concise form—*duration of retinal impression is inversely proportional to the logarithm of the luminosity*, or in the form of the equation

$$D = \frac{1}{k \cdot \log l}.$$

It is interesting to note the similarity of this with Fechner's law* connecting the intensity of stimulus and the sensation

* Revision der Hauptpunkte der Psychophysik (Leipsig), p. 184.

produced. Fechner's law was also empirically deduced and has since been confirmed, for mean values, by Dalbouf's memoir to the Belgian Academy. It can be expressed in the form

$$s = k_{,} \cdot \log\ x$$

where s denotes intensity of sensation and x intensity of stimulus. In this particular case the stimulus is luminosity, hence we have

$$D = \frac{1}{k_{,,} \cdot s}$$

which means simply that retinal persistence varies inversely as the intensity of the sensation producing it. This seems to agree with ordinary experience and thus to confirm the validity of the law connecting retinal persistence and luminosity.

Effect of Age upon Retinal Persistence.

It was thought that possibly as a person advanced in years, the retina might become selective in its sensitiveness for different colors and that therefore the curve of duration of retinal impression might be different from that of a younger person. Two professors in the University kindly permitted their eyes to be tested for retinal persistence and the values obtained are given in the annexed table.

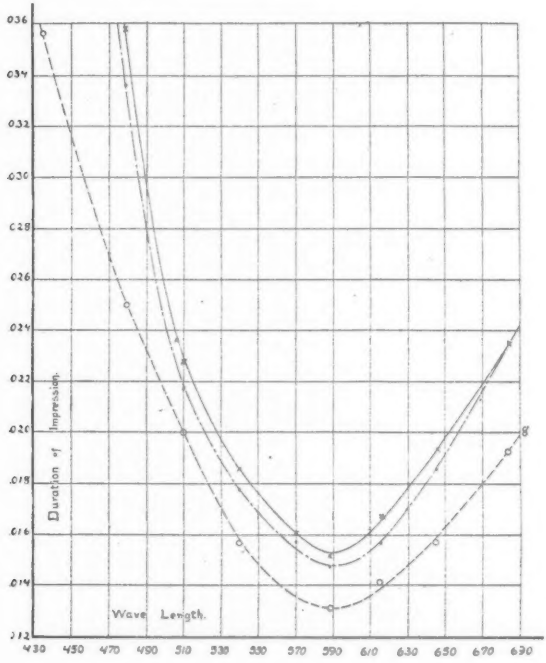
TABLE VII.

Wave-length. λ	Duration of retinal impression in seconds. Prof. S. G. W.	Prof. E. L. N.
·435	·0417	·0417
·480	·0333	·0357
·510	·0217	·0227
·540	·0179	·0185
·570	·0156	·0161
·589	·0147	·0155
·615	·0156	·0166
·645	·0185	·0192
·684	·0227	·0227

These values platted in fig. 5 seem to indicate that for both Dr. Nichols and Prof. Williams the more refrangible part of the spectrum is proportionately less luminous than to the eyes assumed to be normal. But the violet end of the spectrum is so feeble that observations in it are very difficult, and certainty cannot be obtained without more extended observations. If anything can be deduced from so few observations, these curves show to a high degree of probability that age increases retinal persistence to a considerable amount and that

the increase is nearly uniform for all wave-lengths. This fact would be naturally expected, for it is well known that age decreases retinal sensitiveness; and as the sensitiveness decreases the action of the retina would be less quick either to receive an impression or to dismiss one.

5



Summary of Results.

I. The duration of retinal impression is very different for different regions in the spectrum, being at a minimum value at the region of maximum luminosity and gradually increasing to maximum values at the ends of the spectrum.

II. If the luminosity of any region in the spectrum be so changed that the values vary in geometrical ratio, the corresponding values of duration of impression will approximately vary in arithmetical ratio for regions of ordinary brightness.

III. Color has, at most, very slight influence upon retinal persistence. Luminosity,—including the brightness of the light and the retinal sensitiveness—is the all-important factor.

IV. For ordinary values the following empirical law is approximately true—*Retinal persistence varies inversely as the logarithm of the luminosity.*

V. The values of retinal persistence in dichroic eyes is very different than in normal eyes. For instance, light impressions of red last much longer on the retina of red-blind persons than on the normal, yellow somewhat longer than normal and the other colors about the same as normal. With green-blind persons, green impressions persist much longer than normal, red a little less than normal and the other colors the same as normal.

VI. The very marked departure from the normal values of retinal persistence in dichroic eyes for the region of their lacking color sensation, affords a precise and convenient method of determining color-blindness.

VII. Within the range of these experiments, it seems probable to a high degree that age increases the duration of retinal impressions to a nearly equal amount in all regions of the spectrum.

In conclusion I wish to express my obligation to Mr. E. Gordon Merritt for his very valuable assistance in taking observations in these experiments.

Physical Laboratory of Cornell University, June, 1892.

Art. XXVII.—*Kilauea in April*, 1892; by Rev. Sereno E. Bishop.

[Communication to J. D. Dana, dated Honolulu, April, 30, 1892.]

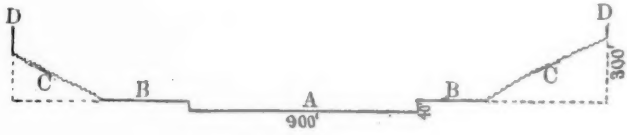
On a visit, a little over a fortnight since to the volcano of Kilauea, the condition of Halemaumau crater was found to be greatly changed from that in 1887, as described in your "Characteristics of Volcanoes," and which I had the satisfaction of observing in your company. It also differs so greatly from what has been hitherto put upon record, that I venture to send you the particulars, with some illustrations for such use as you may choose.

At the collapse of the crater on March 5, 1891, precisely five years after the previous collapse in 1886, a deep open pit was left as before. The great mound* had entirely disappeared into the volcanic depths. The lava speedily reappeared without apparent obstruction, and has since then risen to within about 300 feet of the upper rim of Halemaumau, where it formed a floor of remarkable smoothness. Perhaps two months

*The mound referred to is the "debris-cone" which occupied the interior of Halemaumau, the pit in the southwest part of Kilauea.

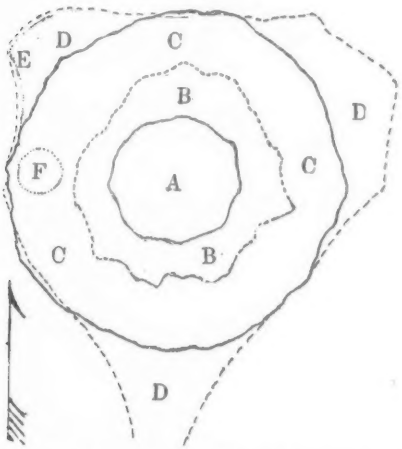
ago it began to subside, and when I last saw it, it was 40 feet below the level of the floor, having sunk about ten feet during five days. The diameter of the molten lake is just about 900 feet, and that of the floor around it averages 1500 feet.

1.



Vertical Section of Halemaumau, April 13, 1892.

2.



Ground-plan of Halemaumau in the southwest part of Kilauea.

Fig. 1 is a ground plan of Halemaumau, and 2, a section of it, as it existed April 13, 1892. In each, A is the Fire-lake of that date 900 feet in diameter; BB, the level floor of blackish lava around the lake, about 40 feet above the surface of the lake, and 1500 feet in diameter; CC, the talus-slope making the chief part of the sides of the pit; D, section of the outer rim of Halemaumau. In the ground-plan, fig. 2, the outer dotted line, is the outline of 1886, as given in Dodge's map; DDD, depressed areas of the pit of that date, filled up by overflows of 1889, 1890, 40 feet above the former level; E, section of former margin of the pit still visible above recent overflows; F, former position of Dana Lake.

The activity of the lake, relatively to its area, is somewhat less than that of Dana Lake as you witnessed it, although

actually several times as great, and exhibiting larger single areas of violent activity. It differs materially from Dana Lake in the distribution of its action. The general movement of the thin crust is steadily from the periphery toward the center, where there is the greatest action. Long seams (fiery cracks) open near the outer edge, and draw inward, crinkling up as they progress, until they become interlaced. An open area of perhaps two acres at the center is occupied by a strong current pouring westward, filled with fragments of crust and exhibiting sparkles of fire with a multitude of small jets and sprays. This current disappears under the crust that extends out from the west side. Near the eastern edge of this central area there is a powerful fountain which did not intermit its action a single minute during several visits from the 8th to the 13th. Its movement was pulsating; about every twenty seconds it welled up in a round billow varying in diameter from 30 to 50 feet, and from 20 to 35 feet high. There was no explosive action, or spray, except what was caused by the falling back of the upheaved fluid.

A similar but smaller fountain played nearer the bank at the south. This, however, at my last visit, had exchanged its action for a more violent but intermittent one. Occasionally, and once for twenty minutes continuously, an area of 150×40 feet was occupied by a violently tossing mass of surges, from 15 to 25 feet high, the entire summit of which was feathery with spray. A similar but smaller area was several times in like action northwest of the center.

The great regurgitating and explosive fountains under the little cliffs, which made the chief displays in Dana Lake, were scarcely to be found here. A slight occasional action of that sort was noticed at two points at the northwest edge.

The remarkable fact is here to be noted, that *no vapor* could be distinguished without careful scrutiny. From the Volcano House, a column of very faint blue haze could be observed ascending, having the diameter of the lake. In the night, this column of vapor, illuminated by the fires, was more discernible. But from the edge of the crater, close at hand, it could barely be distinguished, even by night. I spent many hours on different sides of the crater, once walking around it, but never even perceived any odor of fumes when at the edge, although at some distance from it and all over the floor of Kilauea many crevices were emitting sulphurous fumes. At the present time, the lava seems to have no contact with old rocks near the surface, while the ducts below are doubtless heavily glazed, like those we saw at the bottom of "New Lake" in '87.

The top of Halemaumau crater has been found by aneroid measurement to be from 30 to 50 feet higher than in 1886.

There is every appearance that extensive overflows have taken place over every part of the rim since you were there, and there can be no doubt of a great accumulation of material. The "New Lake" and the intervening depression are totally obliterated. The high promontory west of "New Lake" is lost beneath the flood. The great depression at the south is also filled, though not quite to the general level. The conical form of Halemaumau has become very distinct, and is strongly appreciated in the ascent to it on nearly every side.

The volcano will soon be very accessible for tourists. The Hilo road is perfectly graded and rolled, and will probably be completed in a few months, when the drive to Kilauea will be one wholly of pleasure. The new hotel is a superior one, with lodgings for 70 guests. Plans are in progress for improving the walk over the lava. The whole is now in the hands of an active and enterprising corporation.

ART. XXVIII.—*The Devonian System of Eastern Pennsylvania;* by CHARLES S. PROSSER.

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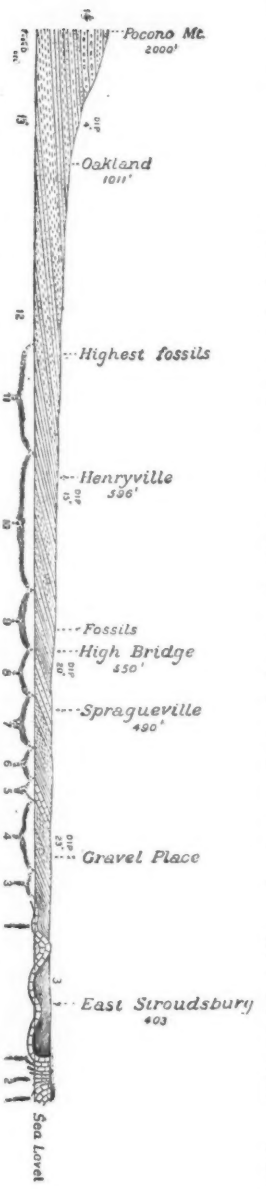
DURING the summers of 1884 and 1890 personal field work in southeastern New York, taken in connection with an opportunity to carefully study the Devonian exposures of this section and those of eastern Pennsylvania in the summer of 1891, is believed to have furnished important data toward the proper correlation of this system with the typical Devonian section of central New York. Numerous sections crossing this series of rocks, with quite a collection of fossils, have been made in the region between the Lehigh river in Pennsylvania and the northern part of Green county, New York. A single section across the Devonian terranes of this district will be briefly described in order to make this work available for use in the construction of the Appalachian geological maps and for the purposes of general correlation. The section along the line of the Delaware, Lackawanna & Western Railroad, crossing Monroe county, Pennsylvania, is considered a typical section and it has been selected for the subject of the present paper. It is no more than just to state that the geologic structure of this region, some of which is decidedly complicated, and the stratigraphic position of the formations have been worked out and mapped by Professors J. P. Lesley* and I. C. White† in an ad-

* The Geology of Pennsylvania, vol. i, 1858, pp. 270–289. For a statement of Prof. Lesley's work in eastern Pennsylvania, see 2d Geol. Surv. Penn., A, p. 102 and *ibid.*, G^6, pp. xiv, xx foot-note.

† *Ibid.*, G^5, The Geology of Pike and Monroe counties, 1882.

mirable manner, the accuracy of which has been personally tested in many localities.

The base of the section is the Upper Helderberg limestone (Corniferous), which is well exposed in the D. L. & W. R. R. cut one mile south of the East Stroudsburg station. The railroad cut is through an anticlinal fold and near the center the Cauda-galli grit is exposed, the limestone at the northern end of the cut being overturned. The Marcellus shales succeed the limestone, one exposure being in the railroad cut a short distance south of the station, and another along McMichaels creek, opposite Elizabeth street, Stroudsburg. Fossils are not generally common, but at the northeastern end of the small ridge north of Scott street, Stroudsburg, is a bluish-black shale in which they are quite abundant.* The following species have been identified from this outcrop. (U. S. Geol. Surv., No. 1475 B[1]).



SECTION ALONG THE DELAWARE, LACKAWANNA & WESTERN RAILROAD FROM EAST STROUDSBURG TO MT. POCONO, PENN.

Horizontal scale 2½ miles to the inch. Vertical scale 500 feet to the inch.

1. Upper Helderberg (Corniferous limestone). 2. Cauda-galli grit. 3. Marcellus shales. 4. Hamilton. 5. Tully limestone of Professor White. 6. Genesee shale of Professor White. 7. Chemung and Portage of Professor White. 8. Staruca sandstone (Upper Chemung of White). 9. New Milford red shale. 10. Delaware river flags. 11. Montrose red shale. 12. Honesdale sandstone. 13. Upper Catskill. (9 to 13 Catskill). 14. (?) Mt. Pleasant Conglomerate (Pocono).

* This locality was mentioned by Prof. White; see 2d Geol. Surv. Penn., G[6], pp. 115, 116.

1. *Leiorhynchus limitaris* (Van.) Hall ..... (*aa*)*
2. *Chonetes mucronata* Hall ..... (*aa*)
3. *Leiopteria lævis* Hall ..... (*c*)
4. *Styliola fissurella* Hall ..... (*c*)
5. *Orthoceras subulatum* Hall (?) ..... (*r*)
6. *Pterinopecten dignatus* Hall ..... (*rr*)
7. *? Goniatites* sp. ..... (*rr*)

About half a mile north of East Stroudsburg, another anticlinal fold brings to the surface the Corniferous limestone and then there are no more noticeable exposures of rocks along the railroad until a point is reached a short distance north of Gravel Place. At this locality, about two and one-half miles from Stroudsburg, are exposures of rather coarse arenaceous shales on the northeast side of the railroad. The fossils are quite abundant, especially *Vitulina pustulosa* Hall. The following species were found at this place (No. 1475 C^2 and C^3).

1. *Vitulina pustulosa* Hall ..... (*aa*) 50 specimens.
2. *Ambocœlia umbonata* (Con.) Hall ..... (*c*)
3. *Phacops rana* (Green) Hall ..... (*r*)
4. *Spirifera mucronata* (Con.) Bill. ..... (*r*)
5. *Chonetes deflecta* Hall ..... (*r*)
6. *Spirifera granulifera* Hall ..... (*rr*)
7. *Modiomorpha subalta* (Con.) Hall ..... (*rr*)
8. *Modiomorpha concentrica* (Con.) Hall (?) ..... (*rr*)
9. *Pterinea flabellata* (Con.) Hall ..... (*rr*)
10. *Palæoneilo constricta* (Con.) Hall ..... (*rr*)
11. *Leiorhynchus multicosta* Hall ..... (*rr*)
12. *Pleurotomaria* sp. ..... (*rr*)
13. Crinoid, calyx ..... (*rr*)

It will be noticed that the above list is a typical Hamilton fauna and these arenaceous shales and thin sandstones make an outcrop nearly one mile in width.

Near the top of the above zone is an arenaceous, slightly calcareous shale which in places, especially where not weathered, forms a massive stratum of very compact rock. There is a good exposure of this zone by the side of the Stroudsburg and Spragueville highway, on the western side of Brodhead creek about one and one-half miles below Spragueville and a short distance south of Mr. E. Bonynge's house.† Fossils are very abundant at this exposure, especially corals and crinoid stems; but there are also numerous specimens of brachiopods.

Fauna of No. 1475 C^5.

* The relative abundance of the species is indicated as follows:
aa = very abundant, *a* = abundant, *cc* = very common, *c* = common, *r* = rare, *rr* = very rare.

† This locality is described by Prof. White in G^6, pp. 109, 271 under the heading of the "Tully Limestone horizon."

1. *Spirifera sculptilis* Hall ..... (*a*)
2. *Spirifera fimbriata* (Con.) Hall* ..... (*a*)
3. *Spirifera mucronata* (Con.) Bill ..... (*c*)
4. *Orthis Vanuxemi* Hall ..... (*c*)
5. *Nucleospira concinna* Hall ..... (*c*)
6. *Athyris spiriferoides* (Eaton) Hall ..... (*c*)
7. *Phacops rana* (Green) Hall ..... (*c*)
8. *Cypricardinia indenta* (Con.) Hall ..... (*c*)
9. *Atrypa reticularis* (Linn.) Dal. ..... (*c*)
10. *Cyrtina hamiltonensis* Hall ..... (*r*)
11. *Tropidoleptus carinatus* (Con.) Hall ..... (*rr*)
12. *Chonetes coronata* (Con.) Hall ..... (*rr*)
13. *Strophodonta perplana* (Con.) Hall (?) ..... (*rr*)
14. *Leiorhynchus multicosta* Hall (?) ..... (*rr*)
15. *Actinopteria decussata* Hall (?) ..... (*r*)
16. *Mytelarca* (*Plithomytilus*) *oviformis* (Con.) Hall ..... (*rr*)
17. *Conocardium* sp. ..... (*rr*)
18. *Platyceras* sp. ..... (*rr*)

Corals and Bryozoa.

This horizon is especially important since Professor White considered it to be at the summit of the Hamilton stage and to represent the Tully limestone of New York. After describing the locality from which the above species were collected, the Professor stated "There can be little doubt that this stratum represents the *Tully limestone horizon* of the New York Reports, and it thus becomes a valuable guide in correlating and classifying the rocks of the district."† However, when this zone is studied carefully it will be noticed that it is usually a calcareous shale or sandstone, instead of a massive limestone and does not lithologically resemble the Tully limestone of central New York. But, far more important than the lithologic character of the zone, is the fact that the fauna therein contained is composed of Hamilton species, while those which are especially characteristic of the Tully limestone are absent.‡ This zone appears to the writer to correspond with the calcareous layers that occur in the midst of the regular Hamilton shales of central New York rather than with the Tully limestone.

While considering the correlation of this zone it is impor-

* *Spirifer fimbriatus* Morton was proposed in 1836, this Jour., vol. xxix, p. 150, pl. II, fig. 1; while Conrad's *Delthyris fimbriatus* was named in 1842, Jour. Acad. Nat. Sci., Philadelphia, vol. viii. p. 263. S. A. Miller in 1883, 2d ed. Am. Pal. Foss. named Conrad's species *Spirifera Conradana;* but in this paper the name by which the New York species is generally known has been retained.

† G^6, p. 109.

‡ For a list of the New York Tully fauna with a discussion of the species having a diagnostic value, see a paper by Prof. H. S. Williams on "The Cuboides zone and its fauna; a discussion of methods of correlation," Bull. Geol. Soc. Am., vol. i, pp. 490–494.

tant to recall the known limit of the eastern extension of the Tully limestone of central New York, which formation was found by Vanuxem in Chenango county " at the northwestern part of Smyrna, on the road to DeRuyter village, where the road crosses the west branch of the Chenango [river]."* In the summer of 1886 the writer studied this region, and near Upperville in Smyrna township reported limestone layers separated by calcareous shales, twenty-five feet in thickness.† Farther east in the Unadilla valley no representative of the zone was found.

One fourth mile farther north than the outcrop of the calcareous, coral zone, the highway crosses Brodhead creek and under the bridge and along the banks of the stream are exposures of rather finely arenaceous, bluish shales which are moderately fossiliferous. This zone is easily traced in the field on account of its being composed of thin, dark-colored shales which succeed the coarse arenaceous shales of the middle and lower Hamilton. One of the best localities for collecting fossils in this zone is in the gorge of the Sawkill creek, above Milford, Pike county, and the fauna of that station will be given for this horizon. (See fauna of No. 14767².)

The outcrop from which this fauna was obtained is one of the typical exposures of this zone, which was referred by Professor White to the Genesee shale. The fossils came from the upper part of the zone as exposed in the gorge of the Sawkill, which "rapidly excavates a long narrow cañon out of the *Genesee shale*."‡ While under the description of the geological formations, Professor White says that "the top of the *Hamilton* is marked off everywhere in this district by the appearance of a dark sandy fossil slate or shale, which seems to be identical with the *Genesee black slate* of the New York Reports."§

A geologist familiar with the Genesee shale of central and western New York will find some difficulty in correlating this zone with the New York Genesee. These shales have

* Geol. New York, Pt. III, 1842, p. 292. Also, see p. 164.

† Proc. Am. Assoc. Adv. Sci., vol. xxxvi, 1887, p. 210.

‡ G⁶, p. 199.

§ *Ibid.*, p. 107. Professor Lesley called these shales Genesee in the explanation of the geological structure of Monroe Co., Report X, 1885, p. lxxx.

Mr. Arthur Winslow in his work along the Lehigh river named the continuation of these shales Genesee, and mentioned them particularly at Weissport (Ann Rept. Geol. Surv. Penn., 1886, Pt. IV, pp. 1365, 1367, 1371). Also, see Winslow's map and section from exposures along the Lehigh river, sheet No. 3. In the continuation of the Lehigh section down the river by Mr. Frank A. Hill, similar shales are called Genesee (*Ibid.*, pp. 1373, 1374). A considerable collection of fossils was made from near the Weissport station of the Central Railroad of New Jersey, and from the R. R. cut above Bowmans; the lithologic character of the shale and the fauna is about the same as in the exposures of the same zone farther northeast in Monroe and Pike counties.

FAUNA OF NO. 1476 F²; WITH TABLE OF GEOLOGIC RANGE.

Number of Species.	List of Species.	Abundance.	Geologic Stage.*									
			Oriskany.	Schoharie grit.	Upper Helderberg.	Marcellus shale.	Hamilton.	Tully limestone.	Genesee shale.	Portage.	Ithaca.	Chemung.
1	*Nucula corbuliformis* Hall	*a*	--	--	--	--	×	--	--	--	?	--
2	*Tellinopsis subemaryinata* (Con.) Hall	*a*	--	--	--	--	×	--	--	--	--	--
3	*Palæoneilo constricta* (Con.) Hall	*c*	--	--	--	--	×	--	--	×	×	--
4	*Nuculites triqueter* Con.	*c*	--	--	--	?	×	--	--	-	--	--
5	*Modiomorpha mytiloides* (Con.) Hall	*c*	--	--	--	--	×	--	--	--	--	--
6	*Phacops rana* (Green) Hall	*c*	--	--	?	×	×	×	--	--	--	×
7	*Chonetes mucronata* Hall	*c*	--	--	×	×	×	--	--	--	--	--
8	*Hyolithes aclis* Hall	*c*	--	--	--	--	×	--	--	×	--	--
9	*Pleurotomaria ltys* Hall	*c*	--	--	--	--	×	--	--	--	--	--
10	*Nuculites oblongatus* Con.	*r*	--	--	--	--	×	--	--	×	--	--
11	*Spirifera fimbriata* (Con.) Bill.	*r*	×	×	×	--	×	×	--	--	×	×
12	*Palæoneilo muta* Hall	*rr*	--	--	--	--	×	--	--	--	--	--
13	*Leda diversa* Hall	*rr*	--	--	--	--	×	--	--	--	--	--
14	*Leda rostellata* (Con.) Hall	*rr*	--	--	--	--	×	--	--	×	--	--
15	*Orthonota carinata* Con.	*rr*	--	--	--	--	×	--	--	--	--	--
16	*Prothyris lanceolata* Hall	*rr*	--	--	--	--	×	--	--	×	--	--
17	*Pholadella radiata* (Con.) Hall	*rr*	--	--	--	--	×	--	--	--	×	--
18	*Goniophora carinata* (Con.) Hall (?)	*rr*	--	--	--	--	--	--	--	×	--	--
19	*Modiella pygmæa* (Con.) Hall	*rr*	--	--	--	--	×	--	--	--	--	--
20	*Orthonota* (?) *parvula* Hall	*rr*	--	--	--	--	×	--	--	--	--	--
21	*Athyris spiriferoides* (Eaton) Hall	*rr*	--	--	×	--	×	--	--	--	--	--
22	*Tropidoleptus carinatus* (Con.) Hall	*rr*	--	--	--	--	×	--	--	×	--	×
23	*Ambocœlia umbonata* (Con.) Hall	*rr*	--	--	--	×	×	×	×	--	×	?
24	*Coleolus tenuicinctum* Hall	*rr*	--	--	--	--	×	--	--	--	--	--
25	*Loxonema delphicola* Hall (?)	*rr*	--	--	--	--	×	--	--	--	--	--
26	*Bellerophon leda* Hall	*rr*	--	--	--	--	×	--	--	--	--	--
27	*Dalmanites* (*Cryphæus*) *Boothi* (Green) Hall, possibly the var. *calliteles* Green	*rr*	--	--	×	×	×	×	--	--	--	--
28	*Orthoceras* sp. fragments	*rr*	--	--	--	--	--	--	--	--	--	--
29	*Spirifera granulifera* Hall (?)	*rr*	--	--	--	--	×	--	--	--	--	--
30	*Grammysia lirata* Hall ?)	*rr*	--	--	--	--	×	--	--	--	--	--
31	*Cyclonema hamiltoniæ* Hall (?)	*rr*	--	--	--	--	×	--	--	--	--	--
32	*Bellerophon brevilineatus* Con. (?)	*rr*	--	--	--	--	×	--	--	--	--	--

* The data used in showing the geologic range of the species in the above list are derived principally from the various works of Professors Hall, H. S. Williams, and Clarke, and the distribution is confined mainly to New York. The reported occurrence of certain species farther south along the line of the Appalachians is intentionally left out of consideration, until further investigation shall enable us to compare their stratigraphic position and faunas more carefully with the New York series. Consequently the range of each species is based upon references concerning the reliability of which there is believed to be no question, or upon data that are personally known to be accurate This is a principle that is frequently ignored in the preparation of large tables of distribution and range of species.

very little lithologic resemblance to the Genesee and the list of fossils given above shows that the fauna is not that of the Genesee, but rather one of the Upper Hamilton stage. Only one species of the list identified from the upper shale of the Sawkill cañon has been reported from the Genesee shale of New York, viz: *Ambocœlia umbonata* (Con.) Hall.*

In central New York the Genesee shale does not extend much farther east than the Tully limestone. Near Smyrna the writer found black, argillaceous shales some twenty feet in thickness† and Vanuxem reported it farther east at North New Berlin,‡ now New Berlin. In 1883 the exposures along the valley of the Unadilla river to New Berlin and then across the hills to Oneonta were carefully studied; but no evidence was found of the Genesee black shale or its fauna.

The rather fissile Genesee (?) shales are succeeded by coarser, arenaceous shales alternating with sandstones of moderate thickness. The sandstones are slightly greenish-gray in color, quite micaceous and in lithologic appearance decidedly different from the darker and more argillaceous shales below. Fossils are not common in this zone, but occasionally occur abundantly in thin layers. In the ledges along the hill-sides east of the highway, and by the side of the county road, just above the D. L. & W. R. R. crossing, about one-half mile south of Sprague ville, are exposures of these arenaceous shales containing fossils.

The fauna of No. 1475 $C^{6, 7, \text{and } 8}$ is as follows:

1. *Palæoneilo plana* Hall.....(*a*)
2. *Nuculites oblongatus* Con.....(*a*)
3. *Palæoneilo emarginata* (Con.) Hall (?) var.....(*c*)
5. *Spirifera mesastrialis* Hall.....(*c*)
6. (?) *Actinopteria* cf. *Boydi* Hall.....(*c*)
7. *Nuculites* cf. *cuneiformis* Con.....(*c*)
8. *Prothyris lanceolata* Hall.....(*r*)
9. *Microdon* (*Cypricardella*) *gregarius* Hall.....(*r*)
10. *Spirifera mesacostalis* Hall.....(*r*)
11. *Orthonota* (?) *parvula* Hall (?).....(*rr*)
12. *Nucula corbuliformis* Hall.....(*rr*)
13. *Tropidoleptus carinatus* (Con.) Hall.....(*rr*)
14. *Homalonotus De Kayi* (Green) Em.....(*rr*)
15. *Leptodesma Rogersi* Hall (?).....(*rr*)

The rocks from which the above fauna was obtained are a typical exposure of those which have been called Chemung by

* Dr. J. M. Clarke in 1885 gave a list of fifty-five species that had been found in the Genesee shale of New York (Bull. U. S. Geol. Surv., No. 16, pp. 33, 69, 70). To this fauna he has since added additional species; see, Am. Geol., vol. viii, August 1891, pp. 88–91.

† Proc. Am. Assoc. Adv. Sci., vol. xxxvi, p. 210.

‡ Geol. New York, Pt. III, p. 292.

Professor I. C. White in eastern Pennsylvania. In describing this exposure Professor White said: "Along the county road, about one-half mile below Sprague ville, the *Chemung rocks* are seen in cliffs of gray, fine-grained sandstone, quite *fossiliferous*;"* and in his account of the geologic formations he further stated that "It was impossible to identify any of the beds between the base of the *Catskill* and the top of the *Hamilton* with the *Portage series* of other portions of Pennsylvania, either on lithological or palæontological grounds, and hence I have applied the name *Chemung* to the entire interval, preferring to regard the *Portage series* as absent from this district."† Several reasons are given for this correlation, that of first importance being "The occurrence of characteristic *Chemung fossils* throughout the entire interval."‡ Later, in describing the geology of the Susquehanna river region, Professor White stated that probably the beds in the lower part of the Chemung "are the equivalents of the *Portage beds* in New York;"§ and in a letter dated February 22, 1892, emphasizes the fact that he wishes the above statement to apply to Monroe and Pike counties, and that the lower part of the terrane called Chemung in those counties corresponds to the Portage of New York.

The fauna of this formation is not characteristic of the Chemung stage of southern central and western New York, or even of the highest fossiliferous pre Carboniferous rocks of southern Pennsylvania and western Maryland. On the contrary it is a modified Hamilton fauna, similar to the faunas that occur in central and eastern New York in the Portage, especially after the Tully limestone and Genesee shale have disappeared. It hardly seems to be so late as the "Ithaca group," but rather approaches the earlier modified stages of the Hamilton fauna, as possibly the *Paracyclas lirata* stage of Professor H. S. Williams, which is found well developed above the horizon of the Genesee shale at Oneonta and Norwich in central New York.‖

It is true that *Spirifera disjuncta* Sow. is reported from this formation;¶ and if the specimens were correctly identi-

* G⁶, p. 272. † *Ibid.*, p. 104. ‡ *Ibid.*, p. 104.

§ G⁷, 1883, p. 68; and see pp. 70 and 228 for similar statements.

‖ See Prof. H. S. Williams, Proc. Am. Assoc. Adv. Sci., vol. xxxiv, p. 225 and chart; and Prosser, *ibid.*, vol. xxxvi, p. 210. This fauna characterized the Oneonta group of Conrad (not Vanuxem, who applied the same name to the overlying gray and red sandstones and shales) which was composed of bluish shales with some sandstones and abundantly fossiliferous. The zone is well exposed in the quarry at the foot of the hill west of Oneonta, at Norwich in the quarry near the reservoir, and in the lower part of the high hill west of the village. For Conrad's description of the "group" see Ann. Geol. Rept., N. Y. 1841, pp. 30, 31, 50, 53.

¶ G⁶, p. 105.

fied that would be almost conclusive proof of its Chemung age. But the writer has failed to find this species on the eastern side of the Pocono and Catskill mountains and is inclined to think that *Spirifera mesastrialis* Hall, an allied species which is not uncommon, is the one reported for *S. disjuncta*, especially since the Cascade section of Susquehanna County, Penn., has been reported to contain "well-known Chemung shaly and flaggy strata full of *Spirifera disjuncta*."* When the section was examined in company with Professor H. S. Williams it was found that the common species was *S. mesastrialis*, which had evidently been mistaken for the *S. disjuncta*.†

After considerable field work in southeastern New York and northeastern Pennsylvania, the conclusion is reached that the marine faunas terminated either slightly in advance or soon after the appearance of the Chemung stage. In central and southern Pennsylvania and western Maryland, the conditions seem to have been more favorable and *Spirifera disjuncta* with other Chemung species occurs in rocks which are stratigraphically equivalent to the unfossiliferous beds farther toward the northeast. The geological collections of Johns Hopkins University contain a few specimens of *Spirifera disjuncta* from near Cumberland, Maryland,‡ and Professors Claypole,§ White,‖ Stevenson,¶ Ashburner,** and Meek†† have reported the species from a number of localities in Pennsylvania and Virginia.

These shales and sandstones of the Chemung series, which contain the highest fossil shells seen by Professor White, are succeeded by greenish-gray, thick-bedded sandstones—the Starucca sandstone of Prof. White—which at that time he considered the base of the Catskill.‡‡ Later, Professor White

* G^5, p. 78.

† See the remarks on the Cascade section by Prof. Williams, who states: "When I examined the section I found no trace of several of the species cited, and only rare and imperfect specimens of *Spirifera disjuncta* and the last stage with *Rhynchonella contracta;* but all the mass of the fauna was *Spirifera mesastrialis* and its legitimate associates, which is a lower fauna belonging to the more eastern part of this general area. The difference between the two *Spiriferas* appears at first glance slight; but they are clearly distinct" (Proc. Am. Assoc. Adv. Sci., vol. xxxiv. p. 231)

‡ See list of Chemung fossils from Maryland by Charles R. Keyes in Johns Hopkins Univ. Circulars, vol. xi, December, 1891, p. 29; which specimens through the courtesy of Dr. W. B. Clark have been personally examined.

§ F^2, pp. 74, 77, 289, 291.

‖ T^3, pp. 98, 183, 194.

¶ T^2, pp. 76, 80, 133, 212, 214, 216, 225, 226; and Amer. Geol., vol. ix. pp. 10 26.

** F, pp. 221, 225.

†† Bull. Phil. Soc., Washington, vol. ii, Appendix, Art. viii, p. 34.

‡‡ G^4, pp. 102, 103. See G^3, 1881, pp. 59, 70, 73 and fig. 10 on p. 77 for the original description of this zone.

states "it seems probable that the 600′ of grayish green beds at the top of the *Chemung* in Pike and Monroe which in G⁶ were referred to the *Catskill,* under the name of *Starucca beds,* may be the equivalent of a portion of the *Upper Chemung* of this district [Susquehanna river region], and therefore erroneously referred to the *Catskill* in G⁶."* In the letter mentioned above Professor White writes that 600′ of sandstones which in G⁶ were put in the Catskill should be added to the Chemung. Referring to the difficulty in separating the Chemung and Catskill the Professor says, "I think the only possible separation of Chemung and Catskill is that founded upon physical characteristics and in my opinion we should separate them at the horizon of the *lowest* red beds, for these seem to come in at about the same general zone everywhere, and it is the only possible means of separation." The Starucca sandstone is well exposed at Sprague ville and in the first D. L. & W. R. R. cut north of the station.

The second railroad cut, just north of the Brodhead creek railroad bridge, is in the New Milford red shale, which is now regarded by Professor White as forming the base of the Catskill. The red shales alternate with gray shales and sandstones as far as the "High Bridge" over the West Branch of Brodhead creek where the Delaware river flags of White are reached.† At the southern end of the first railroad cut north of "High Bridge," in the lower part of the Delaware flags, a greenish-gray sandstone contains many impressions of *Orthonota* (?) *parvula* Hall,‡ a species that occurs in the upper Hamilton shales of Schoharie county, New York, as well as frequently in the argillaceous Hamilton shales of central and western New York. There is also a breccia which contains fragments of brachiopod shells and fish bones. At the northern end of the cut are coarse, grayish, arenaceous shales in which fern-stipes occur, and one poorly preserved frond of *Archæopteris minor* Lx. (?) was found.

The Delaware flags are succeeded by the Montrose red shale in the vicinity of Henryville,§ and overlying these shales are the Honesdale sandstones. Near the transition from

*G⁷, p. 73. † See G⁶, p. 100.

‡ Dr. Charles E. Beecher has seen these specimens and agrees with the above identification. Dr. J. M. Clarke has kindly compared some of the specimens with the types in the New York State Museum at Albany, and writes: "I see no reason why the shells in question should not be regarded as *Orthonota* (?) *parvula* in accordance with your identification; I have compared them with the types of *O.* (?) *parvula* and can find no distinctive characters."

§ From the railroad cut in the red shale, just south of Henryville station, Prof. White reported *Archæopteris Jacksoni* Dn. (G⁶, pp 103, 320). No specimens were found by the writer and the only fossils seen in the shale were fucoidal (?) fragments, which are frequently seen in the red shales of the Chemung and Catskill.

White's Montrose shale to the Honesdale sandstones, as exposed along the D. L. & W. R.R, occurs the highest fauna that has yet been found in Monroe and Pike counties. Above these shells no fossils were seen in the higher rocks, except undeterminable fragments of plants. The shells occur in some greenish, argillaceous shales, about one and one-half feet above red shales at the northern end of the second railroad cut north of Henryville. Several good specimens of *Spirifera mesastrialis* Hall were found and one of *Leda diversa* Hall (?). *Spirifera mesastrialis* which is reported from the Hamilton of Schoharie county, New York,* is an abundant and well known species of the middle zone of the "Ithaca group" at Ithaca and is also found in the lower Chemung farther south in southern central New York† and northern Pennsylvania,‡ while *Leda diversa* is a Hamilton species of eastern and central New York. The fossils seem to indicate that these shales are hardly younger than the lower Chemung and they might be still older, since the specimens of *Spirifera mesastrialis* do not appear to be the variety which is found in the lower Chemung of southern New York; but on the contrary the form found in the older rocks of the Portage. The nearest correlation to the above is that of Professor Stevenson in his Vice-Presidential address before Section E of the American Association, in 1891, when he drew the line, separating the Catskill from the Chemung, between the Montrose sandstone above and the Montrose red shale below,§ which is at a part of the series not distant from the horizon in which the *Spiriferas* were collected above Henryville.

Above this horizon coarse, gray sandstones and shales alternate with reddish shales. A thick mass of the red shale is well exposed in the railroad cut just west of Oakland. The cut below Mt. Pocono shows coarse, gray sandstone with fragments of fossil plants, thin, bluish, argillaceous shales, breccia and red shales, while in places the coarse gray sandstone contains quartz pebbles and is probably near the horizon of Professsor White's Cherry Ridge conglomerate, about 500 feet below the top of the Catskill.‖ In general structure and lithologic appearance, these rocks are very similar to the typical Catskill of the Catskill Mountains.

On the summit of the Pocono plateau, about two and one-half miles north of Tobyhanna, is a massive conglomerate which is considered by Professor White as the Mt. Pleasant conglomerate at the base of the Pocono.¶

* Geol. Surv. N. Y., Palæontology, vol. iv, Pt. I, p. 417.
† Bull. U. S. Geol. Surv., No 3, pp. 17, 22, 24.
‡ Proc. Am. Assoc. Adv. Science, vol. xxxiv, p. 231.
§ Am. Geol., vol. ix. p. 14.
‖ G^6, p. 78. foot note.
¶ G^6, pp. 80, 329.

Conclusions.—As a result of this investigation no change is suggested for the Lower Devonian—the Cauda-galli grit and Upper Helderberg (Corniferous limestone). In the Middle Devonian the Marcellus is generally clearly defined, except in the upper part where it changes rather gradually from the argillaceous to the more arenaceous shales of the overlying Hamilton stage. The Hamilton as mapped and defined consists mostly of rather coarse arenaceous shales and thin sandstones; but to these possibly should be added the calcareo-arenaceous zone (called Tully limestone) and the black, fossiliferous shales above (called Genesee). It is shown that the so-called Tully and Genesee stages do not agree with the New York formations in either lithologic or paleontologic characters. After the disappearance of the Tully limestone and Genesee black shale in central New York there is very little evidence of their reappearance in eastern New York. Therefore the correlation of the zones in Pennsylvania with these New York formations is considered as open to discussion. The Chemung series contains a modified Hamilton fauna similar to that in the lower Portage of central New York, after the disappearance of the Tully limestone and Genesee shale. Above this fauna are the Starucca sandstones, the New Milford red shales, the Delaware flags with *Orthonota* (?) *parvula*, and the Montrose shales in the upper part of which *Spirifera mesastrialis* and *Leda diversa* (?) occur. These fossils seem to indicate that up to this horizon this series of rocks may not be of later geologic age than the lower part of the Chemung stage. From the above statement the inability to indicate any sharp dividing line between the Catskill and Chemung series, or the Chemung and Portage stages, will be readily understood.

Acknowledgment is due to Mr. Charles D. Walcott, Chief Paleontologist of the U. S. Geological Survey, and to Professors H. S. Williams of Cornell University, I. C. White of West Virginia University, and Lester F. Ward of the U. S. Geological Survey for suggestions and advice in this work.

U. S. Geological Survey, May, 1892.

Art. XXIX.—*On the Cæsium-Mercuric Halides;* by H. L. Wells.

It is to be expected that more complete series of double-halides can be made with cæsium than with the other alkali-metals, because it is the extreme member of the potassium group and the most electro-positive element known, and because cæsium double-salts in general are less soluble than the corresponding compounds of the other alkali-metals. A thorough

study of these compounds seems desirable since very little work has been done in this direction, and therefore the present investigation of the cæsium-mercuric chlorides, bromides and iodides has been undertaken.

The following is a complete list of the previously described mercuric double-halides containing the alkali-metals and ammonium, as far as I have been able to find them:

Na_2HgCl_4	NH_4HgCl_3	$RbHg_2Cl_5$
Rb_2HgCl_4	$RbHgCl_3$	$KHg_2Cl_5 . 2H_2O$
Cs_2HgCl_4	$KHgBr_3$	
$(NH_4)_2HgBr_4$	$NH_4HgCl_3 . \frac{1}{2}H_2O$	
K_2HgBr_4	$KHgCl_3 . H_2O$	$(NH_4)_2Hg_2Cl_6 . 4H_2O$
Na_2HgI_4	$KHgBr_3 . H_2O$	
K_2HgI_4	$NaHgCl_3 . 1\frac{1}{2}H_2O$	
$(NH_4)_2HgCl_4 . H_2O$	$NH_4HgI_3 . 1\frac{1}{2}H_2O$	$(NH_4)_2Hg_9Cl_{20}$
$K_2HgCl_4 . H_2O$	$KHgI_3 . 1\frac{1}{2}H_2O$	
$Rb_2HgCl_4 . 2H_2O$		
$(NH_4)_2HgI_4 . 3H_2O$		

The greater number of these arrange themselves into two types with varying water of crystallization or with none. There are two compounds of a third type, while the two remaining, more complicated salts, stand alone. The last two were described by Holmes.*

An effort has been made to make the examination of the cæsium-mercuric salts very complete, but it is not safe to say that every possible compound has been prepared, for negative results are uncertain. It will not be necessary to describe the unsuccessful experiments where mixtures or uncertain products were obtained. It is sufficient to say that other double-halides were repeatedly looked for in every direction, and every indication of a new salt was followed up until a homogeneous product was obtained and analyzed.

The following table gives a list of the salts that are to be described. One of them, Cs_2HgCl_4, has already been prepared by Godeffroy.†

I.	II.	III.
Cs_3HgCl_5	Cs_2HgCl_4	$CsHgCl_3$‡
Cs_3HgBr_5	Cs_2HgBr_4	$CsHgBr_3$‡
Cs_3HgI_5	Cs_2HgI_4	$CsHgI_3$
$Cs_3HgCl_3Br_2$	$Cs_2HgCl_2Br_2$	$CsHgClBr_2$‡
$Cs_3HgBr_3I_2$	$Cs_2HgBr_2I_2$‡	$CsHgBrI_2$
	$Cs_2HgCl_2I_2$	
IV.	V.	VI.
	$CsHg_2Cl_5$	$CsHg_5Cl_{11}$
	$CsHg_2Br_5$	
$Cs_2Hg_3I_8$	$CsHg_2I_5$	
	$CsHg_2ClBr_4$	$CsHg_5ClBr_{10}$

* Chem. News, v, 351.

† Berichte, viii, 9.

‡ These compounds are dimorphous.

These salts confirm the composition of all the previously known alkaline-mercuric halides, as given in the preceding table, except the single compound $(NH_4)_2Hg_9Cl_{20}$. It is extremely probable, however, that the correct formula for this is $NH_4Hg_5Cl_{11}$, for Holmes obtained results slightly lower than his theory in his ammonium determinations, and it would be scarcely possible to distinguish between the two formulas by analysis, as will be seen from the following numbers:

	Calculated for $(NH_4)_2Hg_9Cl_{20}$.	Calculated for $NH_4Hg_5Cl_{11}$.	Differences.
Mercury	70·70	71·00	0·30
Ammonium	1·41	1·27	0·14

The differences between the amounts of mercury and cæsium for the corresponding formulas are 0·80 and 0·85, so that it is evident that the cæsium compound furnishes a far better means of determining the composition of the salts.

The first type, Cs_3HgHl_5, is a new one. These compounds are interesting as exceptions to Remsen's law concerning the composition of double-halides.*

The salt $Cs_2Hg_3I_8$, although standing alone among the cæsium compounds, is a very well characterized body, and the compound $(NH_4)_2Hg_3Cl_8 . 4H_2O$, made by Holmes, belongs to the same type.

The results of the work on the cæsium-mercuric salts fulfill the expectations concerning the value of cæsium as a means of studying alkaline double-halides, for all the previously discovered types have been made with this metal, and one besides that had never been discovered.

Preparation.

The compounds were made by dissolving mercuric halides in hot solutions of cæsium halides and cooling, or in some cases evaporating at ordinary temperatures, to crystallization. The relative amounts of the two halides and the dilution both have an important influence in determining the salt produced. In most cases dilution with water is equivalent to the addition of mercury, while concentration produces the same effect as the addition of a cæsium halide. It has been noticed, where more than one salt is deposited from a solution by cooling, that the salts with more mercuric halides are formed first. This shows that cooling a solution may be equivalent to the addition of cæsium.

There are only a few of the salts that can be recrystallized unchanged from water, most of them requiring the presence of an excess of cæsium halide, or in two or three cases mercuric

* Am. Chem. Jour., xi, 296; xiv, 85.

halide, for their formation. Crystallization from water can therefore often be used for preparing one salt from another.

All the compounds were made with solutions of the normal salts without the use of acids. Some of them have been made with alcoholic solutions, but this solvent has not been found to possess any advantages except for preparing $CsHg_2I_5$.

Analytical Methods.

The salts were always carefully examined to be sure that they were not mixtures. Many mixed crops of crystals were obtained, but I am confident that the products analyzed were pure. The crystals for analysis were always quickly and thoroughly freed from the mother-liquor by pressing repeatedly between smooth filter-papers, and, at the same time, they were crushed to remove included liquid. During this drying process the substances were exposed to the air as little as possible to avoid any evaporation of the adhering liquid before its removal. After the products had been dried as thoroughly as possible in this way, they were usually exposed to the air for an hour or two to remove the last traces of moisture, but this was not done in a few cases where I wished to be certain that no easily-lost water of crystallization was present.

Portions of about one gram of substance were usually taken for analysis. In no case was the analysis hampered from lack of material. The chlorides and bromides were readily dissolved in water, but it was necessary in analyzing the iodine compounds to dissolve them in water containing alcohol. Mercury was invariably determined as sulphide, the precipitate being collected, dried at 100° and weighed on an asbestos filter in a Gooch crucible. Cæsium was usually determined in the filtrate from the mercuric sulphide and was always weighed as sulphate. In this operation the excess of sulphuric acid was removed by ignition in a current of air containing ammonia, as suggested by Krüss for potassium sulphate. In some cases where cæsium alone was to be determined, the substance was weighed out directly into a platinum crucible, sulphuric acid was added, the excess of this and the mercury were removed by evaporation and heating and normal cæsium sulphate was weighed. The halogens were invariably determined in separate portions and were weighed as silver salts. In the cases where two were present, they were determined by heating the mixed silver halides to constant weight in chlorine.

The Double-chlorides.

These are all white in color and are permanent when exposed to the air. On recrystallizing from water all of them finally yield $CsHgCl_3$.

Cs_3HgCl_5 is made by dissolving a comparatively small quantity of mercuric chloride in a nearly saturated cæsium chloride solution. It is deposited on cooling, but the best crystals are obtained by spontaneous evaporation. If too much of the mercuric compound is added or if too much water is present, other double salts or mixed products will be obtained. On the other hand, if too little mercuric chloride is present, cæsium chloride crystallizes out. The limits of the conditions under which it is formed are narrow, but by repeated trials, with slight variations suggested by previous results, a pure product is readily obtained. It forms slender, radiating prisms which are easily distinguished from the compounds with which it is liable to be mixed.

The following analysis was made of a sample which was rapidly dried on paper, but not air-dried. The small amount of water found was probably simply moisture. It was determined by direct weighing in a calcium-chloride tube.

	Found.	Calculated for Cs_3HgCl_5.
Cæsium	51·15	51·38
Mercury	24·84	25·76
Chlorine	21·79	22·86
Water	1·69	0·00
	99·47	100·00

Cs_2HgCl_4 is produced, by cooling a hot solution, when a little more mercuric chloride or water is used than in the case of the last salt. The conditions for its formation are narrow. It forms large but usually very thin plates which are readily distinguished from the other double-chlorides. A sample was dried on paper for analysis.

	Found.	Calculated for Cs_2HgCl_4.
Cæsium	44·06	43·75
Mercury	----	32·90
Chlorine	22·87	23·35
Water	0·52	0·00
		100·00

$CsHgCl_3$ is dimorphous, forming, according to circumstances, cubic or orthorhombic crystals. The cubic form is produced, under widely varying conditions by cooling dilute aqueous solutions, when cæsium chloride is considerably in excess. The orthorhombic form is deposited when cæsium chloride is not in great excess and by one or more recrystal-

lizations from water of all the double chlorides. This form can be recrystallized from water indefinitely.

The compound is practically insoluble in absolute alcohol, but it dissolves in alcohol diluted with about one-third of its volume of water, and it is remarkable that the *cubic form* is deposited from such a solution on cooling.

The cubes often form peculiar aggregates, apparently of a pyramidal shape. The orthorhombic crystals are very brilliant and highly modified, usually forming groups of spear-shaped individuals joined end to end.

Three samples were analyzed; A, cubes simply dried on paper; B, cubes from alcohol; C, orthorhombic crystals, air-dry.

	Found.			Calculated for $CsHgCl_3$
	A	B	C	
Cæsium	30·29	30·26	29·92	30·26
Mercury	44·80	....	45·63	45·51
Chlorine	23·40	....	24·03	24·23
Water	1.42	....	....	0·00
	99·91		99·58	100·00

Since the orthorhombic form of this compound is not decomposed by water its solubility could be determined. This was done by analyzing the mother-liquor from a third recrystallization at about 17°. Of this solution, 100 parts contained 0·4255 parts of cæsium, corresponding to 1·406 parts of $CsHgCl_3$.

$CsHg_2Cl_5$ was made by dissolving 24 g. of $CsHgCl_3$ and 16 g. of $HgCl_2$ (a little more than one molecule of the latter) in about 150 c. c. of hot water and cooling. A large crop of needles was obtained which were undoubtedly homogeneous.

	Analysis gave.	Calculated for $CsHg_2Cl_5$.
Cæsium	18·13	18·72
Mercury	56·32	56·30
Chlorine	24·68	24·98
	99·13	100·00

The salt is not very readily decomposed by water, but by repeated recrystallization the orthorhombic form of $CsHgCl_3$ is obtained.

$CsHg_5Cl_{11}$ was prepared by making a nearly saturated solution of 12·5 g. of $HgCsCl_3$ and 38·5 g. of $HgCl_2$ (about one molecule of CsCl to six of $HgCl_2$) in boiling water and cooling. The compound was obtained in prisms, so well formed

that there was no doubt about their homogeneity. Two crops were analyzed.

	Found.		Calculated for $CsHg_5Cl_{11}$.
Cæsium	8·68	8·51	8·73
Mercury	65·59	----	65·64
Chlorine	24·97	----	25.63
	99·24		100·00

A single recrystallization of this salt from water gave a mixed crop of crystals and this, on repeating the operation, gave $CsHg_2Cl_5$ still containing a little of the original compound. This last crop was analyzed.

	Found.	Calculated for $CsHg_2Cl_5$.
Cæsium	15·57	18·72

The Double Bromides.

All of these salts are white, or nearly so, except $CsHgBr_3$ which has a lemon-yellow color. This color is remarkable since CsBr and $HgBr_2$ are both pure white.

All of the double bromides yield $CsHg_2Br_5$ on recrystallizing them one or more times from water. It is to be noticed that this salt belongs to a different type from the double-chloride which is stable with water, but if alcohol is used for recrystallizing this bromide, the salt corresponding to the chloride just mentioned is deposited.

Cs_3HgBr_5.—The preparation of this salt is exactly analogous to that of the corresponding chloride, and it has the same appearance.

	Found.	Calculated for Cs_3HgBr_5.
Cæsium	39·83	39·94
Mercury	19·50	20.02
Bromine	39·60	40·04
	98·93	100·00

Cs_2HgBr_4 is prepared similarly to the chloride, but the limits of the conditions under which it is formed are much wider. Like the chloride it usually forms very thin plates, but they can sometimes be produced of sufficient thickness for measurement. Three separate crops, made under considerably different conditions were analyzed.

	Found			Calculated for Cs_2HgBr_4.
Cæsium	33·84	34·43	33·69	33.84
Mercury	25·68	25·11	25·45	25·45
Bromine	40·48	40·40	40·52	40.71
	100·00	99·94	99·66	100·00

$CsHgBr_3$.—This compound is dimorphous, but while one form is cubic, like one of the chlorides, the other is monoclinic and has no apparent relation to the orthorhombic chloride. Just as in the case of the chlorides, the cubic form is produced when an excess of the cæsium halide is present, while the second form is deposited when this excess is not as great. Unlike the corresponding chloride, the second form of the bromide is decomposed by recrystallization from water, the salt $CsHg_2Br_5$ being formed, but, as will be noticed beyond, the opposite transformation can be produced by recrystallizing the last mentioned salt from alcohol. The limits of formation of the cubic salt are wide, but it is difficult to produce the other form in a pure state, and it is possible that the monoclinic crystals analyzed were mixed with a small quantity of the cubes.

	Found		Calculated for $CsHgBr_3$.
	Cubic.	Monoclinic.	
Cæsium	23·18	22·89	23·21
Mercury	34·95	35·54	34.90
Bromine	41·70	41·63	41·89
	99·83	100·06	100·00

$CsHg_2Br_5$.—The recrystallization of any of the other double-bromides from water produces this salt, and it can be recrystallized indefinitely without decomposition. It forms very small, thin plates which have a very faint tinge of yellow. By spontaneous evaporation of a mother-liquor from a recrystallization of this salt somewhat larger crystals were formed. Three separate crops were analyzed.

		Found.		Calculated for $CsHg_2Br_5$.
Cæsium	14·60	14·69	13·24	14·26
Mercury	42·71	....	....	42·87
Bromine	42·55	....	....	42.87
	99·86			100.00

The mother-liquor from a third recrystallization from water at about 16° was found to contain 0·1151 per cent of cæsium, corresponding to solubility of 0·807 parts of $CsHg_2Br_5$ in 100

parts of the solution. The salt dissolves rather sparingly in hot, strong alcohol and, on cooling this solution, the compound $CsHgBr_3$ separates out.

	Found.	Calculated for $CsHgBr_3$.
Cæsium	22·68	23·21

The crystals thus obtained were not large enough to measure, but it was probable, from microscopic examination, that they were the monoclinic form of this compound. This is interesting from the fact that it is the cubic form of $CsHgCl_3$ which crystallizes from alcoholic solutions.

No satisfactory crops of crystals were obtained from solutions made with $CsHg_2Cl_5$ and $HgBr_2$ together.

The Double Iodides.

These salts are all yellow, $CsHg_2I_5$ and $Cs_2Hg_3I_8$ having a color nearly like that of normal potassium chromate, while the others become paler as the cæsium chloride increases. All of them are decomposed by water, forming compounds containing more mercuric iodide than the original salt, or, at last, mercuric iodide itself. It is therefore possible to take any one of these double-salts, and, by recrystallizing from water and evaporating the resulting solutions, to prepare the complete series of five double-iodides, as well as the component simple iodides, without the use of any new material. It is noticeable that the iodides differ from the chlorides and bromides in not including a salt that can be recrystallized continually from water. This peculiarity is doubtless due to the comparative insolubility of mercuric iodide. In most cases, the analyses of the salts containing iodine show an excess of mercury and a deficiency of the halogen (or halogens). It is not known whether this was due to some impurity in the salts or to analytical errors. It is not considered probable that inaccuracies in the analyses could have caused so much variation from theory, for the methods used were the same as for the chlorides and bromides, except that alcohol was used as a solvent, and, while halogens and mercury were always determined in separate portions, the summations of the analyses were usually satisfactory.

Cs_2HgI_4.—This salt, like the corresponding chloride and bromide, requires for its preparation a very concentrated solution of the cæsium halide containing a relatively small amount of the mercuric compound. It crystallizes well and may be obtained either by cooling or spontaneous evaporation. The crystals form peculiar, steep pyramids.

	Found.	Calculated for Cs_3HgI_5.
Cæsium	33·02	32·33
Mercury	16·33	16·21
Iodine	50·42	51·46
	99·77	100·00

Its specific gravity taken in benzol was found to be 4·605.

When this salt is dissolved in a small quantity of hot water the compound Cs_2HgI_4 crystallizes out on cooling, but with a larger quantity of water everything remains in solution.

Cs_2HgI_4.—This salt is produced under wide limits of conditions by cooling solutions of the component salts when cæsium iodide is in excess. The monoclinic crystals vary in habit, forming long prisms, nearly square plates or intermediate forms. They are often obtained of very large size, sometimes extending completely across the bottom of the vessel containing the solution and turning upwards at the ends besides.

	Found.		Calculated for Cs_2HgI_4.
Cæsium	27·32	27·39	27·31
Mercury	21·57	21·21	20·53
Iodine	51·41	51·49	52·16
	100·30	100·09	100·00

Two determinations of the specific gravity, taken in benzol, gave the numbers 4·799 and 4·812.

The salt is decomposed by water, giving, according to the quantity used, either one of the salts containing more mercuric iodide or mercuric iodide itself. It is not dissolved or decomposed by alcohol.

$CsHgI_3$ (. H_2O ?).—This salt is formed only within very narrow limits from solutions containing a little more mercuric iodide or water than those from which the preceding salt is obtained. These conditions are perhaps most easily reached by dissolving the last salt in a small amount of hot water and cooling. It often happens that the three salts $Cs_2Hg_3I_8$, $CsHgI_3$ and Cs_2HgI_4 are successively deposited as a solution cools, and it is consequently difficult to obtain the salt under consideration in a pure state, but this was accomplished after a great many trials with varying conditions. The compound forms very thin transparent plates which usually radiate from a point and are often of large size. By pressing on paper they rapidly become opaque. Whether this is caused by molecular re-arrangement or loss of water of crystallization is not certain, for, on account of the extreme thinness of the crystals, it was

impossible to decide whether a small amount of moisture or a molecule of very unstable water of crystallization was present. Two samples were analyzed. A was air-dried after pressing on paper; B was quickly dried on paper.

	Found. A.	Calculated for $CsHgI_3$.	Found. B.	Calculated for $CsHgI_3 . H_2O$.
Cæsium	18·81	18·63	18·25	18·17
Mercury	29·29	28·01	28·74	27·33
Iodine	51·50	53·36	50·98	52·05
Water	....	0·00	2.51*	2·45
	99·60	100·00	100·48	100·00

Like all the other iodides, this salt is decomposed by water.

$Cs_2Hg_3I_8$ is formed under widely different conditions. It is most convenient to prepare it by dissolving Cs_2HgI_4 in the proper amount of hot water and cooling. It is also formed, in a finely divided condition, by treating the same salt with not too much cold water. The crystals vary considerably in habit, but they can be readily distinguished from the other iodides. A characteristic form is a triangular plate, but plates of different shape and more or less elongated prisms often occur. The following analyses were made of separate crops. Sample C was made by treating Cs_2HgI_4 with cold water.

	Found. A.		B.	C.	Calculated for $Cs_2Hg_3I_8$.
Cæsium	13·89	....	14·14	14·07	14·13
Mercury	33·76	....	....	33·83	31·88
Iodine	52·07	52·10	52·63	52·96	53·99
	99·72			100·86	100·00

Specific gravity, taken in benzol, 5·14. The salt dissolves in alcohol. It is decomposed by water with the separation of a part of the mercuric iodide. From the solution thus obtained, the salts containing less mercuric iodide can be prepared by evaporation.

$CsHg_2I_5$.—When a hot aqueous solution of cæsium iodide is saturated with mercuric iodide, this compound is formed on cooling, but, under these conditions, the substance is usually mixed with HgI_2 and often with $Cs_2Hg_3I_8$. When weak alcohol is used as a solvent, however, a pure product is obtained without difficulty. It forms slender yellow prisms which become red on standing in an aqueous mother-liquor. They are more permanent in the solution when it is alcoholic, but, on drying them by pressing on paper, they quickly assume the

* By loss at 100°.

red color of of mercuric iodide without losing their form. It is probable that the spontaneous decomposition results in the formation of $Cs_2Hg_2I_8$ and HgI_2. It was necessary to analyze the material which had become red.

	Found.	Calculated for $CsHg_2I_5$.
Cæsium	11·47	11·39
Mercury	35·73	34·25
Iodine	52·93	54·36
	100·13	100·00

The Mixed Double-halides.

A great deal of labor has been devoted to a study of these compounds in order to find to what extent they could be prepared. The results show that cæsium chloride and mercuric bromide unite readily although there is a tendency towards an exchange of halogens and the formation of unmixed salts. It is also noteworthy that, while there is a double chloride as well as a double bromide which is not decomposed by recrystallization from water, all the chloro-bromides finally yield mercuric bromide when so treated.

The number of bromo-iodides is less than that of the unmixed salts, for, when attempts are made to prepare compounds containing the larger amounts of mercuric iodide, there is an exchange of halogens and almost pure double iodides are produced.

Only one compound of mercuric iodide with cæsium chloride could be prepared. This is $Cs_2HgCl_2I_2$, and the type to which it belongs may probably be considered, on this account, the most stable one of the cæsium-mercuric halides.

It is evident that the mixed salts are not as readily formed as the unmixed, and that the more dissimilar the two halogens are, the less tendency there is to form the mixed compounds.*

In preparing these salts, containing two different halogens, the halogen of higher atomic weight was always added in combination with the mercury. The methods of preparation are exactly analogous to those by which the unmixed salts are made, so that most of these details will be omitted in describing them.

The Chloro-bromides.

In form these all resemble the unmixed salts between which they are intermediate, and all of them are colorless except $CsHgClBr_2$, which is pale yellow.

* This point is discussed in connection with the cæsium trihalides. (Wells and Penfield, this Journal, III, xliii, pp. 31 and 32.)

$Cs_2HgCl_2Br_2$.—

	Found.	Calculated for $Cs_2HgCl_2Br_2$.
Cæsium	48·12	46·10
Mercury	23·80	23·11
Chlorine	16·24	12·30
Bromine	11·82	18·49
	99 98	100·00

The product was made with a very large excess of cæsium chloride, and it contained a considerable amount of the double chloride. The analysis corresponds nearly to the formula $2Cs_2HgCl_2Br_2+Cs_2HgCl_4$.

$Cs_2HgCl_2Br_2$.—Two products, which were made under different conditions, were analyzed.

	Found.		Calculated for $Cs_2HgCl_2Br_2$.
Cæsium	40·34	38·86	38·16
Mercury	28·79	28·58	28·69
Chlorine	12·94	10·48	10·19
Bromine	17·43	22·07	22·96
	99·50	99·99	100·00

One of these crops corresponds very closely to the formula, while the other, made in the presence of a greater excess of cæsium chloride, contains a little Cs_2HgCl_4.

$CsHgClBr_2$.—This has been obtained, like the chloride and bromide, in dimorphous forms. One of these is cubic like the other salts, while the second form crystallizes like the chloride and not like the bromide. The color of both varieties is pale yellow.

	Found.				Calculated for $CsHgClBr_2$.
	Cubic form.	Orthorhombic form. Separate products.			
Cæsium	26·50	26·97	26·74	26·01	25·17
Mercury	38·75	40·21	40·05	38·91	37·84
Chlorine	9·23	11·32	11·42	8·53	6·72
Bromine	25·21	21·63	21·94	26·65	30·27
	99·69	100·13	100·15	100·10	100·00

These products evidently contain some of the chloride. The analyses of the first two samples of the orthorhombic salt correspond closely to the formula, $2CsHgClBr_2+CsHgCl_3$.

$CsHg_2ClBr_4$.—Two separate products, made under different conditions, were analyzed.

	Found.		Calculated for $CsHg_2ClBr_4$.
Cæsium	15·48	15·23	14·97
Mercury	45·72	45·06	45·02
Chlorine	5·75	3·71	3·99
Bromine	32·30	36·06	36·02
	99·25	100·06	100·00

$CsHg_5ClBr_{10}$.—This compound was prepared by recrystallizing the preceding salt from water.

	Found.	Calculated for $CsHg_5ClBr_{10}$.
Cæsium	6·23	6·76
Mercury	52·77	50·80
Chlorine	2·85	1·80
Bromine	38·19	40·64
	100·04	100·00

There is a chloride corresponding to this compound, but no bromide was obtained of this type. It forms elongated crystals much smaller than the chloride. The final product, when this salt is recrystallized from water, is mercuric bromide.

The Bromo-iodides.

Only three of these compounds have been prepared. When attempts were made to obtain compounds containing larger amounts of mercuric iodide, there was an interchange of halogens and nearly pure double iodides were formed. Two such products were analyzed.

	Found.	Calculated for $Cs_2Hg_3I_8$.	Found.	Calculated for $CsHg_2I_5$.
Cæsium	14·69	14·13	11·62	11·39
Mercury	33·72	31·88	36·09	34·25
Bromine	2·19	0·00	2·43	0·00
Iodine	49·58	53·99	49·45	54·36
	100·18	100·00	99·59	100·00

$Cs_3HgBr_3I_2$.—This salt resembles the iodide, not the bromide, in form. Its color is a pale yellow, intermediate between the brighter iodide and the colorless bromide.

	Found.	Calculated for $Cs_3HgBr_3I_2$.
Cæsium	37·21	36·50
Mercury	19·39	18·30
Bromide	25·18	21·96
Iodine	18·24	23·24
	100·02	100·00

$Cs_2HgBr_2I_2$.—This compound has a very faint tinge of yellow. It is apparently dimorphous, although no other salt of this type has been made in more than one form. It occurs in very thin plates, like the chloride, bromide and chlorobromide, and in stout monoclinic crystals like the iodide. The limits of the conditions under which the plates are made are very narrow, and it is difficult to obtain them free from the dimorphous crystals. As the solution cools, however, the plates are deposited first, and, with the proper dilution, it is possible to remove them and get the mother-liquor pressed out with paper before the other crystals begin to form. There is no difficulty in preparing the other modification of the compound.

	Found.		Calculated for $Cs_2HgBr_2I_2$.
	Thin plates.	Orthorhombic crystals.	
Cæsium	30·71	30·20	30·23
Mercury	24·14	23·86	22·73
Bromine	21·05	17·91	18·18
Iodine	24·23	28·50	28·86
	100·13	100·47	100·00

It is noticable that the plates, which resemble the bromide in form, contain a small excess of bromine and a corresponding deficiency of iodine.

$CsHgBrI_2$.—Only one form of this compound has been prepared, although three other salts of this type are dimorphous. Its form is monoclinic, like one modification of the bromide, and it is pale yellow in color.

	Found.	Calculated for $CsHgBrI_2$.
Cæsium	20·26	19·94
Mercury	31·44	29·99
Bromine	13·35	11·99
Iodine	34·39	38·08
	99·44	100·00

The Chloro-iodide, $Cs_2HgCl_2I_2$.

This is the only combination of cæsium chloride and mercuric iodide that could be produced. It is formed only in very concentrated solutions containing a great excess of cæsium chloride. Its form is different from any other salt of the type, for it occurs in slender, radiating needles. It is snow-white in color, and when it is brought in contact with water it instantly becomes bright red from the formation of mercuric iodide. Two entirely separate crops were analyzed.

	Found.		Calculated for $CsHgCl_2I_2$.
Cæsium	33·38	33·14	33·63
Mercury	26·71	....	25·28
Chlorine	8·87	9·01	8·98
Iodine	30·85	30·17	32·11
	99·81		100·00

When it was attempted to make a chloro-iodide containing more mercuric iodide than this, a nearly pure double-iodide was formed by exchange of halogens.

	Found.	Calculated for $Cs_2Hg_3I_8$.
Cæsium	13·76	14·13
Mercury	33·49	31·88
Chlorine	0·16	0·00
Iodine	50·74	53·99
	98·15	100·00

The investigation of double-halides will be continued in this laboratory, and it is hoped that a further study of the cæsium salts will lead to a better knowledge of this class of compounds in general than we now possess.

In conclusion, it gives me pleasure to express my gratitude to my colleague, Professor Penfield, for his hearty coöperation in undertaking the crystallographic examination of the compounds which have been described. His results have been freely used in the foregoing descriptions, and they will be given in detail in a future article.

Sheffield Scientific School, New Haven,
Conn., May, 1892.

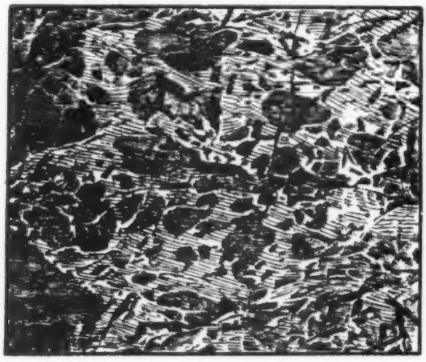
ART. XXX.—*On the relations of the Laurentian and Huronian on the North Side of Lake Huron;* by ALFRED E. BARLOW.

[Published by permission of Dr. Selwyn, Director, Geological Survey of Canada.]

IN this Journal for March, 1892, there appears an article on "The Structural Relations of the Huronian and Basement Complex on the North side of Lake Huron" by Messrs. Pumpelly and Van Hise. On page 228 they refer to an article by me "On the Contact between the Laurentian and Huronian north of Lake Huron" which was published in the American Geologist (vol. vi, 1890, pp. 19–32). The region to which my paper referred might better have been defined as north-east rather than north, as the descriptions related only to certain

portions of the line of junction between Lakes Temiscaming and Panache, the latter locality being over one hundred miles east of Thessalon, near which Messrs. Pumpelly and Van Hise observed the contact. The endeavor to correlate two series of facts concerning rocks so far separated geographically after a brief and hurried visit and over a limited area has only led to more confusion and misunderstanding. Their description of the line of junction between the granite and crystalline schists is a feature very frequently observed in the Laurentian (or basement complex). These schists, however, do not in the least resemble the micaceous schists and quartzites described by me as Huronian in contact with the Laurentian gneiss, for those described by Pumpelly and Van Hise show no clastic structure whatever and seem always to belong to the basement complex (Laurentian) with which they are associated, while the fragmental origin of those described by me may readily be seen in the field or in thin slice under the microscope. Beautiful examples of the mode of occurrence of the Laurentian schists may be seen at the Murray Mine,on the main line of the Canadian Pacific

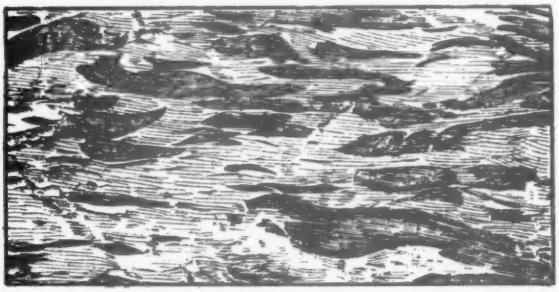
Fig. 1.



Railway, three miles and a half northwest of Sudbury. Here the hornblende schists or amphibolites are seen embedded in a light colored gneissic granite, the pseudo-conglomeratic appearance thus produced being sometimes very marked. (See Fig. 1). In other cases the hornblende schists occur in lenticular patches lying parallel to one another. (See Fig. 2.) Prof. G. H. Williams (see Report Geological Survey of Canada, Part F, 1891, p. 73) classes these amphibolites among the undoubted eruptives and thus describes them: "A fine grained, very dark green or nearly black foliated rock containing a much coarser felspathic or granitic vein. This is a closely interwoven aggregate of

green hornblende and brown biotite. The foliation is produced by the approximate parallelism in the cleavage directions of the minerals. The only other constituents visible under the microscope are quartz and ilmenite surrounded by veins of sphene (leucoxene). Of the origin of this rock we can say nothing now with certainty. It may well have resulted from the ex-

Fig. 2.



treme metamorphism of some basic eruptive, but from a small specimen like this it is unsafe to draw any such conclusion. The feldspathic vein is a much coarser aggregate of quartz, orthoclase and plagioclase with a little green hornblende. The feldspar has many minute hornblende needles secondarily developed in it, but otherwise the rock appears like a fresh granite."

The eruptive origin assigned to this rock by Prof. Williams would seem to agree with its relations in the field and on account of its intimate association with granitoid gneisses we have classed it with the Laurentian and so colored it on the recent maps issued by the Canadian Survey of the Sudbury Mining District. These gentlemen also make me state that I "drew the conclusion that nowhere on the north shore of Lake Huron are any detritals which are later than and rest unconformably upon the basement complex," when in the article is distinctly described (see p. 37, American Geologist, Vol. VI, 1890) a thinly bedded slate conglomerate resting upon the upturned edges of the Laurentian gneiss on Annima-Nipissing Lake.

Briefly then, the Huronian System may be regarded as the oldest series of sedimentary strata of which we have at present any knowledge in this district, while the Laurentian gneiss or basement complex is the original crust of the earth or the firm floor on which the first sediments were laid down. The composition of this floor, judging from the overlying strata, would be closely analogous to granite and the laminated pebbles in the slate conglomerates indicates that this basement had in

many places a foliated or gneissic structure. The immense pressure exerted by the overlying stratiform material, and the crumpling folding and fracturing of the comparatively thin and weak crust consequent on the earth's cooling would all tend to sink large portions of the Huronian below the line of fusion, the submergence of which would produce conditions of contact such as I have described to the north-east of Lake Huron and which subsequent upheaval and denudation have exposed.

At other places the basement complex may have remained undisturbed so that the overlying detritals though somewhat altered have not been intruded or pierced by the granitic mass beneath. The latter doubtless have been the conditions which obtained in the localities visited by Messrs. Pumpelly and Van Hise north of Lake Huron and by me on Annima-Nipissing Lake. The explorations of the past two seasons have served to confirm the opinions expressed in the paper published in the American Geologist and as the region then under examination has just been finished, I hope to move farther west during the coming summer and explore the district visited by these geologists.

Before closing I would like to take exception to the various brief visits paid to certain so-called "typical localities," as the hurried examinations thus made must always lead to confusion. Had Messrs. Pumpelly and Van Hise written to me I would have been only too eager to accompany them to the many points of geological interest exhibited in this district. It is often so easy then to reconcile seemingly opposite views, whereas a letter in reply, no matter how written, only leads to endless and sometimes useless discussion.

Art. XXXI.—*Some Convenient Forms of Laboratory Apparatus;* by F. A. Gooch.

[Contributions from the Kent Chemical Laboratory of Yale College—XVI.]

Burette Clip.—A simple and effective device to replace the Erdmann float (which has well-known disadvantages) in getting exact burette readings is made by cutting thin springy brass, or copper, or other metal to the form of a letter **H**, shaping it as shown in fig. 1 so that it will cling to a burette with the cross-bar vertical, and fastening to the cross-bar a fold of white paper ruled longitudinally with a heavy, sharply defined, dark line. The clip may be made to hold firmly to any burette, while capable of easy upward and downward motion, and is

1.

readily removable and replaceable when it becomes necessary to pass the point of support of the burette. The refractive action of the meniscus upon the dark line upon the white background acts just as in the enamelled burettes which have recently come into use, and serves to define exactly the level of the liquid. Errors of parallax in observing are easily avoided by placing the eye in such position before reading that the front segment of the circle nearly completed by the edge of the upper ring falls into coincidence in perspective with the back segment as shown in the figure.

Apparatus support.—The simple device illustrated in fig. 2 and fig. 3 has been in use for several years in this laboratory wherever a rod support is desirable and has almost entirely replaced the movable stand which students usually find unwieldy and difficult to dispose of in limited space. The brass fitting into which is cut a strong screw thread, as shown in fig. 2, is set directly in the face of the work table with its upper surface flush with that of the table, and is held in place firmly by screws if the table-top is of wood, or by bolts and nuts if the table top is of soapstone or other material which does not afford holding ground for ordinary screws. Iron rods of sizes and lengths suited to holding all sorts of apparatus, from the lighter forms used in elementary laboratory instruction to the heavier lecture apparatus, are cut with screws matching the thread of the brass fitting and may be set firmly in place as shown in the figures. The rods are of course interchangeable as occasion may require. When stripped of apparatus the rod takes up very little table space, but if a clear table is desired, it is easy to remove the rod by means of tongs kept at hand for the purpose in the laboratory toolbox. This device is neat, inexpensive, and easily made by any worker in brass and iron.

2

3

Steam evaporator.—A convenient, simple and inexpensive form of individual steam-bowl is easily constructed in the form shown in fig. 4 wherever steam connections are available. An ordinary glass funnel of suitable size is hung in an iron ring, for holding which the rod support previously described serves admirably. The stem of the funnel is cut off short and a T-tube is attached as shown, set in a short piece of rubber tub-

ing, with the lower end of the vertical branch bent to make a water-trap, while the horizontal branch is connected with the steam supply. A pipe to convey away the condensed water which overflows from the trap is a convenience, but in the absence of a drip-pipe any suitable receptacle may serve a similar purpose. Ordinary water-bath rings adapt the funnel to vessels of various sizes, but the funnel itself serves efficiently in holding several different sizes of round-bottomed dishes. The transparency of the funnel makes it possible to regulate the steam supply so as to secure the maximum heating effect without saturating the surrounding atmosphere with waste steam. Of course, if it is desirable, several of these steam-baths may be hung to the same rod.

4.

Mercury washer.—Various forms of mercury-washing machines have been proposed and used with success. The particular form here described and shown in fig. 5, differs essentially from its predecessors only in the degree of fineness to which the impure mercury is reduced when it is brought into contact with the purifying medium. In this apparatus the impure mercury, liquid enough to flow readily, runs of its own weight from the uppermost funnel through the supply arm of a glass atomizer through the other arm of which compressed air is admitted in force sufficient to break the thin stream of mercury to fine dust. Thus thoroughly comminuted, and presenting the maximum surface to the liquid, the mercury falls into dilute nitric acid, from which it passes to distilled water, and thence to the dry receiver. Funnels fitted with outlet tubes set in rubber stoppers, as shown in the figure answer well for containing vessels, and the rod and socket device described above serves as a support for the apparatus. In the case of the particular apparatus which I have used

5.

the air was admitted to the atomizer under a pressure of about one-third of an atmosphere above the ordinary.

Certain experiments made to determine whether ferric chloride or chromic acid might be used in the purifier instead of dilute nitric acid showed that the superficial effect of these reagents upon the extremely finely comminuted mercury prevents the reunion of the particles even when submitted to considerable pressure. When dilute nitric acid is employed no such difficulty arises.

ART. XXXII.—*Note on the change of electric conductivity observed in rock magmas of different composition on passing from liquid to solid;* by CARL BARUS and JOSEPH P. IDDINGS.

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§ 1. *Introduction.*—The chemical composition of rock magmas and the process and results of their crystallization and solidification have been studied with more or less thoroughness; but direct investigation of their physical properties has not been systematically undertaken until recently.

Conceptions of the physical nature of molten rock magmas, however, have been obtained by observing the phenomena of their crystallization, and by pointing out analogies between the latter and the behavior of aqueous solutions, and of metallic alloys.

Evidences that a chemico-physical differentiation of molten magmas was the cause of chemical differences in igneous rocks, which evidences have been reviewed by one of us in a paper on the origin of such rocks,* have led to the further analogy between this process of differentiation and the concentration and partial dissociation of salts in aqueous solution. They also suggested the possibility of testing the fact of dissociation by electrolytic investigation.

The method employed was the determination of the electric resistance encountered by a current in passing through fused rock magma, whose temperature was gradually lowered. The investigation, though of a preliminary character has been productive of such definite results that we have embodied them in the present paper in order that they may become known as early as possible.

§ 2. *Observations.*—The following table contains typical ex-

*J. P. Iddings. The origin of igneous rocks, Bull. Phil. Soc. Washington, 8°. Washington, 1892, vol. xii, pp. 89–214.

amples of sixteen series of electric measurements made with three kinds of rock magmas, which cooled slowly in a furnace from the molten state. Temperatures* and resistances were noted simultaneously every two minutes during each series. The resistances were measured by Kohlrausch's method of intermittent currents. The data for mean temperatures are closely accordant, but at very high temperatures and at low temperature sharpness is lost, owing to polarization and to the immense range of electrolytic resistances encountered. These difficulties are largely unavoidable, although our method is capable of much improvement. Reductions to absolute values are approximate.

TABLE I.

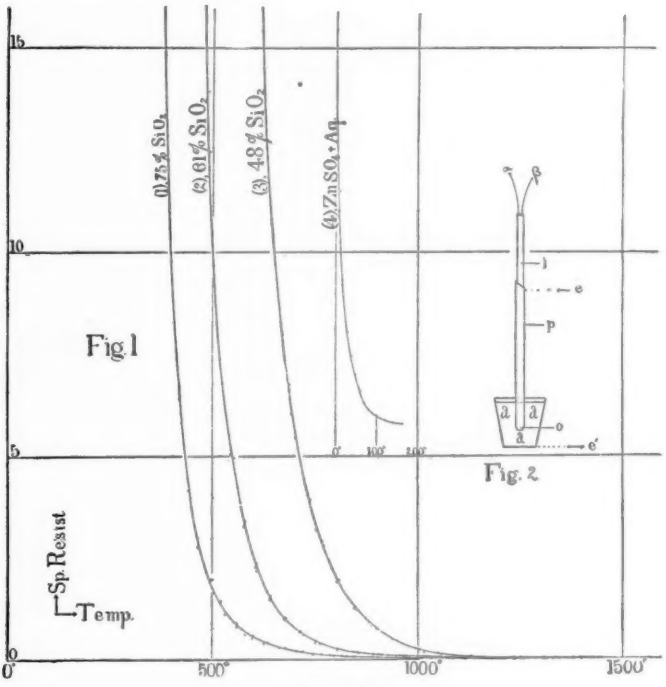
Table 1. *The specific electrolytic resistances of rock magmas, varying with temperature and composition.*

1. Acid magma. 75·50 per cent SiO_2.			2. Intermediate magma. 61·5 per cent SiO_2.			3. Basic magma. 48·5 per cent SiO_2.		
Series.	Temperature.	Resistance.	Series.	Temperature.	Resistance.	Series.	Temperature.	Resistance.
xiv	°C	ohms × 10^6	xiii	°C	ohms × 10^6	viii	°C	ohms × 10^6
	1640	1·8		1430	1·8		1400	2·9
	1320	2·2		1260	2·5		1230	4·4
	1164	2·9		1114	4·2		1124	5·4
	1086	3·1		1034	6·3		1050	14·7
	1011	3·8		956	8·8		995	27·8
	948	4·7		894	13·4		939	54·7
	890	6·5		843	20·0		883	94·0
	827	8·0		754	46·4		834	152
	787	11·6		715	70·2		792	227
	746	15·3		680	105		754	321
	705	21·6		643	158		723	432
	665	29·5		608	239		692	602
	626	41·3		580	344		645	1000
	598	53·8		552	497		612	1400
	582	64·2		496	1140			
	560	82·2						
	533	114						
	504	166						
	467	281						
	444	417						
	425	584						
	395	1060						
	355	2540						
	320	5700						

The results of these observations have been plotted as in the diagram, fig. 1, the ordinates being specific resistances in

* Regarding temperature measurements see Phil. Mag., July, p. 1, 1892.

megohms, the abscissæ temperatures in °C. The curves (which, as shown, contain *all* our observations) are numbered (1), (2), (3), as in Table I, relatively to the magmas. Between 1000° and 1500° the points lie so near the axis, that a discrimi-



Legends.

FIG. 1. Chart showing the relation of the specific electrolytic resistance (megohms, *cc*) to Temperature (°C), in case of

(1) An acid magma,
(2) An intermediate magma,
(3) A basic magma.
(4) Zinc sulphate, concentrated aqueous solution. Resistance relative.

FIG. 2. Crucible and appurtenances with the furnace withdrawn:

aaa, rock magma in platinum crucible;
p, tubular platinum electrode;
i, insulator (fire clay) of the thermocouple;
αβ, thermocouple with its junction at *o*;
ee′, electrolytic current (intermittent).

nation is no longer possible. This can be done, however, by expressing the variations of conductivity with temperature for the interval. It is here omitted because it leads to no novelties. The corresponding curve for a concentrated solution of

zinc sulphate in water has been added for comparison. Here the ordinates are ratios in terms of the resistance of the solution at 100°. Points above 100° were obtained under pressure. Fig. 2 explains itself.

A series of observations with another basic magma gave corroborative evidence. The only electrical indication of fusion was found in the case of the basalt (3). It was somewhat above 1100°, but is not certain. The rhyolitic or acid magma (1) changes character suddenly below 500°, for reasons probably accidental which must be further examined. In this rock, which is very viscous even at 1600°, it is almost impossible to free the magma of gas bubbles. We have not been able to make allowance for volume expansion of the magma, and the residual errors are in keeping with this omission. Finally, without sacrificing accuracy of temperature measurement, it is difficult to make the electrodes sufficiently large in area to exclude polarization.

§ 3. *The magmas.*—The magmas investigated represent three phases of igneous rocks from the same region. The first is a rhyolite; the second, a crystalline andesite or porphyrite; and the third, a basalt. The chemical composition of the rocks is shown by the following analyses made by Mr. J. E. Whitfield.

	I.	II.	III.
SiO_2	75.50	61·50	48·49
TiO_2	none	none	2·19
Al_2O_3	13·25	17·42	18.35
Fe_2O_3	1·02	4·66	7·63
FeO	·91	1·09	1·21
MnO	none	tr.	none
CaO	·90	5·33	10·40
MgO	·07	1·26	6·72
Li_2O	·06	·03	·02
Na_2O	4·76	3·99	3·02
K_2O	2·85	1·29	·57
P_2O_5	none	·60	·20
SO_3	·32	·35	·52
H_2O	·41	2·44	·67
	100·05	99.96	99·99

The three magmas clearly form the middle and extremes of a chemical series.

When heated in a platinum crucible, the basalt melts at about 1250° to a fluid which at slightly higher temperatures becomes quite liquid, and upon solidification forms a black glass that is brown in the thinnest edges and is without gas bubbles.

The porphyrite when heated decrepitates, and afterward fuses in the neighborhood of 1400°, but does not become as liquid as the basalt for like temperatures. It solidifies as a dark brown glass with some gas bubbles.

The rhyolite melts at about 1500°, but remains quite viscid at 1700°, and solidifies as a gray glass filled with minute gas bubbles.

The amount of gas bubbles serves as an indication of the relative viscosity of the different magmas at the temperatures to which they were subjected.

§ 4. *Relation to temperature.*—In making the present deductions the outspoken parts of the data of Table I can alone be taken, viz: in case of the magma (1) between 900° and 500°; in case of (2) below 1034°, and in case of (3) between 1124° and 692°. Careful scrutiny of the relation of resistance to temperature then shows, that the ratio, dr/dt, of corresponding decrements of specific resistance, $-dr$, and of temperature, dt, is proportional to the corresponding resistance at the given temperature. In other words we have $-r' = a + br$, whence

$$ln(a + br) = c - bt \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where a, b, c, are constants. Relative to Table I these values are approximately (r in megohms)

	(1)	(2)	(3)
a	−·10	−·05	+·05
b	·0134	·0125	·0091
c	7·59	8·78	7·96

It is probable that a merely reflects the errors of observation and that its real value is zero. The constant b, which is an index of the composition will be discussed in §§ 5, 6. The quantity c/b, which is a temperature, has no apparent meaning. These results are exceedingly interesting since a relation similar to equation (1) was found* for the thermal variation of the viscosity of a highly viscous body like pitch. Again the acid magmas at least, betray no evidences of circumflexure, or anything that would be an electrical index of polymerism or melting point. An aqueous solution of zinc sulphate carried under pressure through a large interval of temperature, shows changes of resistance† quite akin to the present. In both cases, therefore, we have similar solution phenomena, exhibiting a thoroughly regular change of the electrical character with temperature.

Moreover the nature of the law embodied in equation (1), for silicates, the enormous range of temperatures to which they

* Proc. Am. Acad., xxvii, p. 13. 1892.
† This Journal, xlii, p. 135, 1891.

can be exposed, the extreme sensitiveness of the electrical indications, and the simplicity of the necessary apparatus, suggest a method of pyrometry specially available for temperature approaching the melting point of platinum. One would obviously select an exceedingly acid magma, both because of its relatively great infusibility, and because of the occurrence of the maximum of uniform electrical conduction, in such a case, as will be shown in the next paragraphs.

§ 5. *Relations to chemical composition.* — Endeavoring to interpret these results with reference to their chemical bearing by means of Kohlrausch's* law we are handicapped at the outset because the rates of procession of ions (Hittorf's "Überführungszahlen") in silicate solutions are not known. In other words the quantities expressing the velocity of either ion relative to the combined velocities of both are unknown. We cannot even state what the structure of the electrochemical equivalents may be. It makes a difference whether the cations travel singly or in groups, or whether the anions be $\frac{1}{2}SiO_3$, $\frac{1}{4}SiO_4$, etc., singly or combined. We could not therefore express more than a mere opinion relative to the velocities of the ions, even if the specific molecular conductivities were computed. Nevertheless, in the face of these difficulties we are able to deduce certain striking results insomuch as the method of this paper is one in which the cation is brought gradually, and as nearly as possible to vanish in amount. An index of acidity, independent of temperature, is given by the constant b of equation (1). We regard the anions, whatever their specific structure may be, as identical in the three magmas examined; and the cations, from the large number of elements contained in the magmas, as possessed of a common or average property.

Several general deductions, however, may be drawn from the work, incomplete as it is at present. In the first place, Table I shows strikingly that electric conduction increases with the degree of the acidity of the magma, that is, with the degree of dilution of the cation. And since fusibility decreases in a marked way as the composition of the magma approaches pure silica, it follows that *in a series of different magmas electric conduction at any given temperature increases in proportion as the viscosity increases.*

Thus the most acid of the rocks investigated, (1), is a stiff paste above 1500,° whereas the basalt, (3), can be poured at a temperature much below 1300°; and yet the rhyolite, in virtue of its acidity is a better conductor than basalt at any given temperature.

* Kohlrausch, Wied. Ann., vi, pp. 145 et seq., 1879.

The table also shows that the conductivity of rock magmas at high temperatures is considerable even when they have passed from a liquid to a solid state, that is, when they exist as highly heated glasses.

In general, therefore, a thorough change of chemical structure through ionic diffusion, whether directed by an electrical field or otherwise, must be an easy possibility in a sufficiently temperatured but otherwise solid magma.

§ 6. The second point gained is more specific. Kohlrausch* has shown that the contribution of a single ion in promoting electrical conductivity decreases with the number of ions present. In other words in concentrated solutions the ions are stopped *en route* by what may be termed friction, but what is probably temporary intercombination with each other. Hence their mean velocity, and consequently the specific molecular conductivity of the solution falls short of the proportionate quantity. Moreover, it is perfectly well known† that many solutions (H_2SO_4, HCl, $ZnSO_4$ etc.) show maxima of electric conductivity for gradual changes of concentration. The case of an aqueous electrolyte decreasing in electric conductivity with increasing concentration is therefore given by many examples, and doubtless their number could be indefinitely increased by employing aqueous solutions at high temperatures under pressure.

Now this is exactly what we observe in our series of three silicate solutions. Conduction increases markedly from (3) to (1), that is, from basic to acid, and it seems altogether probable that the anticipative maximum will correspond to a degree of silicic dilution greater than 75 per cent of silica.

Tracing this inference further we come to the conclusion that pure silica is probably an insulator, or that it occupies a position in siliceous electrolysis very closely analogous to that of water in aqueous electrolysis. It is to be remarked that we here refer to the electrolytic solvent and leave the question of chemical solvent temporarily out of consideration. This is in accord with the observations of Warburg,‡ who has elaborately investigated the insulation of a film of pure silica at about 300,° the film having been produced by the electrolysis of glass. The insulator was found to be so perfect that the capacity of the condenser was measureable. The insulation of quartz relative to glass has to some extent (as far as 224°) been tested by Warburg and Tegetmeier,§ though the conditions were complicated in this instance both by crystalline structure and the impurity of the mineral.

* Kohlrausch, l. c. p. 183. † l. c. p. 43.
‡ Warburg, Wied. Ann., xxi, p. 622, 1884.
§ Warburg and Tegetmeier, Wied. Ann., xxxv, p. 463, 466, 1888.

§ 7. *Conclusion.*—Looking at our results as a whole we find them trenching in a novel way on the solution theories of Arrhenius, Ostwald and vant' Hoff. It is difficult to withhold one's assent from the proposition, that the ions of a molten magma are largely present in the dissociated state, and more especially so as we approach very acid magmas. Terms like *colloid* applied to these magmas are absolutely without relevancy so far as we can make out. To the extent of our enquiry, the behavior of molten rock magmas is in its nature quite identical with that of any aqueous or other solution, the difference being one of solvent.

The above paragraphs give a mere draft of a series of experiments which we propose to carry out with greater vigor. We desire, however, to express our conviction that electrolytic resistance is not only a valuable aid to petrological research, but that the definition of molecular structure is possibly within the reach of the method.

Art. XXXIII.—*Estimation and Dehydration of Silver Oxide;* by M. Carey Lea.

In some analytical determinations it became necessary to estimate silver oxide and the question arose at what temperature the moist oxide could be perfectly dried, and also at what temperature it began to lose oxygen. As no such data are to be found, they had to be determined, and the results obtained may possibly be of use to others.

Moist oxide precipitated by perfectly pure sodium hydrate obtained from metallic sodium, and thoroughly washed, was dried at 100° C. for 20 hours. Of this material 1·5528 grams was taken and heated again to 100° for 20 more hours, after which heating it weighed 1·5524, a loss of 0·0004 grams. It was next heated to 160°–165° C. for five hours and was then found to weigh 1·5389 grams, a loss of 0·0135 gram. It was then replaced in the oven and heated 5 more hours. No loss whatever of weight could be detected resulting from this second heating. The oxide was then ignited and gave 1·4358 grams of silver.

Taking the atomic weight of silver at 107·66 and O = 16 argentic oxide should contain 6·92 per cent of oxygen (more exactly 6·917).

From the foregoing it follows that moist silver oxide dried for 40 hours at 100° lost by ignition	7·51	per cent
The same oxide with 10 hours drying, at 160°–165° C. lost by ignition	6·70	"
Calculation for Ag_2O gives for O	6·92	"

It follows that after 40 hours drying at 100° the oxide has reached a constant weight and still retained 0·59 per cent of moisture. When heated to 160–165° till constant in weight it had lost 0·22 per cent of oxygen.

It was next attempted by a shorter second heating and a lower temperature to expel the water alone. Silver oxide was dried for 20 hours at 100° and was then heated for 2 hours to 130°–135° C. Of this oxide 1·8043 gram was ignited and left 1·6701 gram of silver, indicating a loss by ignition of 7·44 per cent. This was only ·07 less than when the heat was not raised above 100° C., showing that the oxide is not dehydrated by exposure to a temperature of 130°–135° C.

The conclusion to be drawn would apparently be that the point at which the last portions of water were driven off was very close to that at which oxygen began to be disengaged. It can be shown however that this is not so and that oxygen is lost long before the last portions of water escape. This can be proved by the delicate photochloride reaction which I described some years ago. If the silver oxide, dried as above described at 100° C till it reaches a constant weight, is moistened with dilute hydrochloric acid, a chloride is obtained of a deep lilac color. This color always denotes the presence of hemichloride due to the fact that a certain portion of the oxide had been reduced to hemioxide. The hemichloride combining with the white chloride forms a photochloride characterized by the coloration just mentioned.

A really accurate estimation of silver oxide is therefore impossible, as it loses oxygen too easily.

Silver oxide is not supposed to form a hydrate, nevertheless some portion of moisture remains united with it more strongly than some part of the oxygen with which it combines to form a strong base.

But it also appears that the loss of oxygen is very small and soon ceases even at 160°–165° C. For after 5 hours exposure to that temperature, the weight became constant.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Phenomena of Coal-dust Explosions.*—Thorpe has described a lecture experiment to illustrate the phenomena which are observed in explosions wherein light combustible solids like coal dust suspended in the air are the chief combustibles. In coal mines opinions are divided as to whether coal dust alone in the air can give rise to explosions, or whether it can do so only when

mixed with fire damp. The apparatus employed by Thorpe consists of a narrow box of wood 12 feet long and 5 inches square intersected at its middle point by a second similar box 6 ft. long. Both boxes are open at the ends and are provided with lids attached with strong hinges and hasps. They are made of inch oak and are put together with screws. At one end of the long box is a slide; and the end itself fits into a quadrangular box 9 inches square, furnished with a lid on top and a small hole for the introduction of a tube carrying gas. On delivering into the box such an amount of gas as will make an explosive mixture (best from a graduated bell-jar over water) and on strewing coal dust along the entire length of the boxes, a blank cartridge, fired from a pistol through the lid of the box to illustrate the effect of a blast, raised a dust cloud which ignited by the explosion, projects a flame several feet long from the farther end of the box. To illustrate a local explosion of fire damp, the slide at the end of the box is pushed in and an explosive mixture is made in the box beyond it. The slide is then withdrawn and a match applied. The explosion raises a cloud of dust and this by its violent ignition produces a continuous cloud along the whole length of the box which is driven out four or five feet from the remote end. Little heaps of gunpowder, or pieces of touch paper placed at intervals along the box, are rarely fired.—*J. Chem. Soc.*, lxi, 414, May, 1892. G. F. B.

2. *On certain New forms of Carbon.*—A new variety of carbon has been obtained by Luzi. When a piece of porcelain, such as a crucible or crucible-cover, is heated in a blast furnace to the highest attainable temperature, say to 1770° C., the fusing point of platinum, and then the access of air is cut off, the highly heated porcelain is surrounded by a smoky flame, which is allowed to act upon it for ten or fifteen minutes. On removing the piece of porcelain from the furnace, it is found to be covered with a peculiar deposit of carbon. If it was unglazed, the deposited carbon resembles graphite; but if glazed, the deposit is bright and silvery and has a metallic luster, resembling closely a silvered mirror. Portions of the deposit adhere so firmly that they can be polished with a cloth; others separate in the form of mirror-like facets of high luster. Loose portions can be pulled off; and then they curl up into rolls like metal shavings. They are exceedingly light and stick to the fingers like silver leaf. This form of carbon is free from ash and does not contain hydrogen; nor does it give the nitric acid reaction for graphite. Moreover it is absolutely opaque. The author has also examined 17 additional varieties of natural graphite by his nitric acid reaction. Nine of these give the reaction and are therefore graphite proper; eight do not and are therefore included in the second class which he calls graphitite. Of the 31 specimens thus far examined 16 were graphite and 15 graphitite. The blackish-gray substance into which diamond is converted on heating, and which resembles graphite, did not give the nitric acid reaction.—*Ber. Berl. Chem. Ges.* xxv, 214, February, 1892. G. F. B.

3. *On Quinite, the simplest Sugar of the Inosite group.*—Since Maquenne proved inosite to be a six-fold hydroxylized hexamethylene, it was to be expected that the hydroxyl derivatives of this substance which are poorer in oxygen would possess sugar-like properties. BAEYER has now succeeded in reducing the *p*-diketone of hexamethylene by means of sodium amalgam to the glycol of hexamethylene. To purify it, he converted it into the diacetyl derivative and this on saponification with barium hydrate gave the pure glycol, $C_6H_{12}O_2$. It is cistrans-paradioxyhexamethylene and resembles in appearance and behavior a sugar of the mannite group. It is permanent toward permanganate solution and Fehling's solution, tastes at first sweet and then bitter. It is easily soluble in water and alcohol, fuses at 143°–145°, and distils without decomposition. According to its formation it is a hexahydro-hydroquinone, and in that case would afford on heating with chromic acid quinone. Since it possesses sugar-like properties and is the simplest representative of the inosite group, the author proposes for it the name *quinite*. The preparation of this substance opens the way apparently for the production of other hydrobenzene compounds.—*Ber. Berl. Chem. Ges.*, xxv, 1037, March, 1892. G. F. B.

4. *On the Relation between the Color of Compounds and their Chemical Constitution.*—From an extended study of a large number of colored compounds both organic and inorganic, SCHÜTZE has obtained some results going to show a relation between the color of these substances and their chemical constitution. These results he sums up as follows: (1) A displacement of the absorption from the violet toward the red corresponds to the color-changes greenish-yellow, yellow, orange, red, reddish-violet, violet, blue-violet, blue, blue-green, etc.; this order of change being called "lowering the tint." A displacement from red to violet corresponds to an inverse color change, i. e., to a "raising of the tint." (2) Atoms and atomic groups on entering a molecule produce, for compounds of the same chromophore and for the same solvent, a characteristic lowering of color-tint (bathochromic groups) or a raising of the color tint (hypsochromic groups). (3) Hydrocarbon radicals act always bathochromic; so that in homologous series the shade deepens as the molecular mass rises. (4) The color-changing action of the elements of the same periodic group also increases with an increase in the atomic mass. (5) Addition of hydrogen is always accompanied by a raising of the tint. (6) The raising or lowering of the color-tint (displacement of the absorption toward the violet or the red) by the substitution of hypsochromic or bathochromic groups, or by the addition or removal of hydrogen, is the more decided the nearer the chemical change which takes place is to the chromophore. In general the distances of the atoms from one another given by structural formulas correspond to their actual distances; in some cases, however, it appears that as in the di-derivatives of benzene, the substituents in the para position are nearer to each

other than are those in the meta position. (7) These rules hold good only for "monochromophoric" compounds and for such "dichromophoric" ones as have equal color-groups influenced in the same way by the neighboring atoms. The color of an unsymmetrical diazo-compound of the type Y–A–X–A–Z is approximately the same as that of a mixture of the two symmetrical compounds Y–A–X–A–Y and Z–A–X–A–Z.—*Zeitschr. physikal. Chem.*, ix, 109, February, 1892. G. F. B.

5. *On Free Hydroxylamine.*—The assumption that hydroxylamine is not capable of existing free, arose apparently from the presence of water in the process employed. Lobry de Bruyne has now succeeded in isolating it by acting on hydroxylamine hydrochloride dissolved in absolute methyl alcohol, with nearly the theoretical quantity of a concentrated solution of sodium methoxide, at a gentle heat. The sodium chloride produced was filtered off and the filtrate was distilled under a pressure of 160–200^{mm}; since at this reduced pressure the alcohol carried off less hydroxylamine. When most of the alcohol had been thus removed, dry ether was added. This separated the liquid into two layers, the upper containing 5·5 per cent hydroxylamine, the lower 53·5 per cent. The lower layer again distilled under a pressure of 165^{mm} until the temperature rose to 86° gave a solution containing 70 per cent of hydroxylamine. Finally, all the solutions were mixed and distilled under a pressure of 60^{mm}. The residue, containing 80 per cent of hydroxylamine, was fractionated in three portions, the last of which solidified in long needles in the cold receiver. This after pressing between filter paper, contained 99·4 per cent hydroxylamine. In this form it is a hard crystalline mass, very hygroscopic and fusing at about 27·5°. Sodium chloride readily dissolves in it and potassium nitrate liquefies it, so that it resembles water. Sodium attacks it strongly. It is inodorous and somewhat denser than water. When heated rapidly on platinum foil it explodes with a clear yellow flame. It is scarcely soluble in chloroform, benzene, ether, ethyl acetate or carbon disulphide. Exposed to the air it first liquefies and then evaporates. It appears to be stable alone as well as in solution. —*Rec. trav. Chim.*, x, 100; *J. Chem. Soc.*, lxii, 402, April, 1892. G. F. B.

7. *Physical and chemical phenomena under the influence of very low temperatures.*—M. Raoul Pictet states that heat-waves corresponding to low temperatures traverse all bodies with hardly any resistance. A test tube filled with chloroform was placed in a nitrous oxide refrigerator at −120°. A thermometer in the tube showed a gradual fall to −68°·5, when crystallization commenced. On removing the test tube to a refrigerator at −80°, the temperature indicated by the thermometer fell rapidly from −68°·5 to −80, while the crystals formed on the walls of the test tube fused and disappeared. On replacing it in the −120° refrigerator, the temperature rose to −68°·5, and the crystals reappeared. M. Pictet explains these phenomena by supposing his

thermometers to have acted as thermo-dynamometers rather than thermoscopes. While the crystals were forming in the first refrigerator, the radiation from the bulb was neutralized by the latent heat given out by the chloroform in crystallizing, whereas in the warmer refrigerator the crystals did not form, and radiation alone was active. Alcohol and sulphuric ether thermometers were used, which were checked by thermometers containing dry hydrogen at four different pressures.—*Comptes Rendus*, May 30, *Nature*, June 9, 1892. J. T.

8. *New method of determining the specific inductive capacity of a dielectric.*— F. T. Trouton and W. E. Lilly point out that the comparison between the energy of a condenser charged with a certain quantity of electricity, first as an air condenser and secondly with a dielectric sheet between the plates, shows that the energy in the first case is greater than in the second, and therefore the dielectric sheet will be drawn in between the plates; for the electric energy of the system being less after the introduction of the dielectric than before, work must have been done by the electric forces during the operation. The amount of this force depends on the specific inductive capacity of the dielectric, and by observing this force the specific inductive capacity may be determined for any given substance. The authors describe a method of measurement, and show its applicability.—*Phil. Mag.*, June, 1892, pp. 529–532. J. T.

9. *Action of the Electric discharge on Gases and Vapors.*— C. Ludeking has made a number of experiments to determine whether electrolysis takes place in the action of the electric discharge on gases and vapors. He concludes that "some of the phenomena noted were in part due to true electrolysis. Others seem to be 'thermolysis,' that is the compounds are simply dissociated by the heat of the discharge. The predilection of the atoms, thus liberated, for electricity of different kinds would make them, like pith balls, fly to the pole having the charge opposite their own, and thus give the entire phenomenon the appearance in all respects of a true electrolysis, while in reality there is the greatest possible difference."—*Phil. Mag.*, June, 1892, pp. 521–528. J. T.

10. *Ratio between the Electromagnetic and Electrostatic Units.* —A new determination has been made by M. H. Abraham of the value of v. The method employed was that of measuring the capacity of a plane condenser with guard ring in both systems. The value obtained was $v = 299{\cdot}2 \times 10^8$.—*Comptes Rendus*, June 7, 1892. J. T.

11. *Influence of Electrification on Cloud Condensation.*—Mr. John Aitken has studied this subject, using a steam jet—and finds that the mere presence of an electrified body has no influence on the steam jet. In order to produce the increased density the water particles in the jet must be electrified either by direct discharge, or by an inductive discharge, effected either by means of a point or a flame. The increased density produced by electri-

fication is due to an increase in the number of water particles in the jet, by the electrification presenting the small drops coming in contact by their mutual repulsions, in the same manner as the water drops in Lord Rayleigh's experiments with water jets, which scatter more when electrified than when not electrified. The coalescence of the drops in water jets takes place only under the disturbance produced by the presence of an electrified body, while such a disturbance produces no effect on steam jets. The action of electricity does not seem to be positive, as it has no effect on a mixture of hot moist air and cold air. It seems rather to prevent something which takes place in the jet under ordinary conditions. The jet on becoming dense emits a peculiar sound which is the same whatever be the cause of the increased density. But when electrified, along with this sound there is another, due to the discharge of the electricity, which causes the electrified jet to appear to make a louder noise.—*Royal Society*, April 28, 1892; *Nature*, May 26, 1892. J. T.

12. *The thermal variation of viscosity and of electrolytic resistance;* by CARL BARUS.—Experiments made on the effect of temperature (θ) on the viscosity (η) of a very viscous substance like marine glue showed that $\log \eta_{p,\theta} = \log \eta_{p_0} - B\theta$ very fully reproduced the results. The subscripts give the quantities constant and variable; p denotes pressure, and B is constant. For napierian logarithms, absolute measure, ° C., and marine glue, $\eta_{\infty} = 10^{12}$ and $B = \cdot 379$. In other words the rate at which viscosity decreases with temperature at $\theta°$, is proportional to the viscosity at $\theta°$.

Experiments made on the effect of temperature on the electrolytic resistance, r, of a silicate (diabase) within 1500° C., showed that $\log (a+br) = \log (a+br_0) - b\theta$, very fully reproduced the results. Here a and b are constant and a merely reflects the observational errors. For diabase, megohms and °C., $a = \cdot 05$, $b = \cdot 009$, $r_0 = 318 \times 10^6$, napierian logarithms being taken. If a be eliminated, $b = \cdot 010$. In any case, however, the rate at which electrolytic resistance decreases with temperature, at the temperature $\theta°$, is proportional to the resistance at $\theta°$. Hence viscosity and electrolytic resistance conform with the same law, and I infer that a common kinetic principle underlies both. This may be stated thus: The rate at which either configurational or molecular instability increases at the temperature θ, is proportional to the instabilities present in the given volume at that temperature—supposing that the number of unstable configurations, or of unstable molecules, respectively, is at all times small relative to the total number of configurations or molecules. (Cf. this Journal, xlii, p. 135, § 12, 1892.) The thermoelectric equivalent, $d\,e = A\,e\,d\,\theta$, I will soon develop.—*Communicated by the Author.*

13. *Outlines of Theoretical Chemistry*, by LOTHAR MEYER, translated by P. PHILLIPS BEDSON and W. CARLETON WILLIAMS. With a preface by the author. 220 pp. 8vo. London and New York (Longmans, Green & Co.).—The name of the author and

the character of his well known larger work upon Modern Theories of Chemistry are sufficient guarantee of the excellence of this new volume. Although there are a number of admirable books at hand upon the philosophy of modern chemistry, each one may be said to occupy a place and have a peculiar value of its own, and this is particularly true of this work by Professor Meyer. It gives a clear, well balanced discussion of the various topics embraced under the head of theoretical chemistry, and would be read with profit by students in this department of science.

14. *Theoretical Mechanics:* A class book for the elementary stage of the Science and Art Department, by J. SPENCER. 243 pp. 12mo. London, 1892 (Percival and Co.).—This little book, by an author who has had much experience in this line, fills well the place for which it is specially prepared. The principles are clearly stated and liberally illustrated by numerical examples. If the solutions by geometrical methods seem awkward, their use must be ascribed to the fact that the author is not at liberty to assume that his readers have a knowledge of trigonometry.

15. *Die Negativ-Retouche nach Kunst- und Naturgesetzen.* Mit besonderer Berücksichtigung der Operation (Beleuchtung, Entwicklung, Exposition) und des photogr. Publikums. Ein Lehrbuch der künstlerischen Retouche für Berufsphotographen und Retoucheure von HANS ARNOLD 480 pp. Vienna, Pest, Leipzig, 1891 (A. Hartleben).—This is a readable volume in an interesting branch of photography, discussing the several topics with much fullness; the scope of the work is given in the title quoted above in full.

II. GEOLOGY AND MINERALOGY.

1. *Upraised Coral Islands off New Guinea.*—In the course of a journey through British New Guinea, in January last, the indefatigable Administrator, Sir William Macgregor, examined and described several remarkable islands, which he shows to be almost certainly ancient atolls that have been elevated by steady horizontal uplift. The island generally known as Kitava (but called Nowau by the natives) has an area of about five or six square miles. It appears to be surrounded by a fringing reef. Nearly all round the island there is a low and slightly sloping margin covered with trees, and about a quarter of a mile wide. This terminates inland in a steep coral wall, which rises abruptly to the height of 300 or 400 feet, and is covered with forest. Shells in the coral point to a comparatively recent upheaval. From the crest of this wall the land dips gently to a plateau from 50 to 100 feet lower, which occupies the center of the island. The plateau is undulating, has a rich chocolate soil, and being protected from wind by the raised rim, whilst subject to a copious rainfall, it is very fertile. All the people live in the

hollow, so that from the sea the island seems to be uninhabited. The central hollow is drained by filtration through the cracked and porous coral rock. Kwaiawata Island, which is from one and a half to two miles in diameter, showed precisely the same form and structure, and in Gawa Island there is a still more perfect instance of a raised atoll. The coral wall in the last instance rises so abruptly to the height of about 400 feet that part of it has to be climbed by ladders, and the plateau representing the old lagoon is nearly 100 feet below the level of the edge. Iwa, another adjacent island about a mile in diameter is of the same kind, only the gently sloping border has been worn away, and the coral cliff meets the sea nearly all round.—*Proc. Roy. Geograph. Soc.*, June, 1892.

2. *The Origin of Igneous Rocks.*—Mr. J. P. IDDINGS, in a paper read before the Philosophical Society of Washington in June last (Bull., vol. xii), has made a very important contribution to science on the Origin of Igneous Rocks. After mentioning at length the opinions that have been presented on the subject, he considers the intimate relations of the various igneous rocks in mineralogical constitution, and especially in chemical composition, illustrating the subject with a large array of facts and tables of analyses. Further, the associations or groupings of the different kinds of rocks in various regions of eruption and the order of succession in origin or outflow in each region are reviewed. After a careful and judicious survey of these subjects in their various relations, the author presents the following conclusions.

The differences in kinds of igneous rocks are not due to the existence of two or more subterranean zones of unlike magmas, or of zones of unlike rock-material which under physical changes might become such magmas; but they arise from the local differentiation of a common magma; and the series, in any region of eruption, usually commences with a kind having the mean composition of the series and ends with rocks of one or both extremes. Mr. Iddings remarks that this law, while it has its exceptions, holds for all the localities that he had personally studied, and for the order of eruption described by Prof. Judd for the lavas of the Lipari Island, "which began with rocks of intermediate composition and has reached the stage where rhyolite and basalt are being thrown out." Other conclusions are: that the variation in the composition of the rocks of a series of eruptions at any volcanic center is the result of the chemical differentiation of a magma of mean or intermediate composition; that molten magmas are essentially solutions, as put forth by Bunsen—a point illustrated in the experiments by Barus and Iddings described on a preceding page; that in each case those portions of the magma which were the later to crystallize may be considered as having been a solvent for the other portions—a solvent not for the silicates necessarily but for their constituents; that the differentiation in any case is due chiefly to differences in

temperature, the temperature varying with the condition of the source of the magma, its relations to the enclosing material, and other causes.

The views presented by Mr. Iddings tend to simplify greatly the subject of rocks, as the author states in his concluding paragraph: "The confusion which has overtaken the classification of igneous rocks and the burden which is being heaped up by the present tendency to multiply its terminology by creating names for each modification of rock, will find their remedy in a more logical conception of the true nature of the differences and relations of rocks."

3. *Bulletin of the Philosophical Society of Washington*, vol. xi, 618 pp., 8vo. Washington, 1892.—This volume, covering the years 1888 to 1891, inclusive, contains valuable papers by Prof. Langley, Capt. C. E. Dutton, J. P. Iddings, E. D. Preston, F. W. Clarke, J. R. Eastman, Everett Hayden, W. J. McGee, G. H. Eldridge, Whitman Cross, and H. W. Turner.

Captain Dutton's paper "*On the greater problems of Physical Geography*," relates to the earth's form, changes of level, and mountain-making. In it he proposes (on p. 53), the term *isostasy* for "the condition of equilibrium of figure to which gravitation tends to reduce a planetary body irrespective of whether it be homogeneous or not," and discusses "How nearly does the earth's figure approach to isostasy?" He speaks of the theory he presents as a modified form of the theory of Herschel and Babbage. The effects of denudation and transportation in determining movement of material under the law of isostasy are also considered, and concluded to be such along coasts as would shove the material of the sea bottoms landward. Mr. Dutton argues also that they might produce systematic plications like those of the Appalachians, stating as an "important fact that these systematic flexures were mainly formed at the times the sediments were deposited," and that "this is a fact of geologic observation." Whose "observation" is not mentioned.

Mr. Dutton remarks that isostasy offers no explanation of the great permanent changes of level; that its very idea means the conservation of profiles against lowering by denudation on the land and by deposition on the sea-bottom; that the cause of permanent changes in the profiles of the land and sea-bottom, or the real nature of the uplifting force, is an independent one, and to him "an entire mystery." "But," he adds, "I think we may discern one of its attributes, and that is a gradual expansion, or a diminution of density, of the subterranean magmas. If the isostatic force is operative at all, this expansion is a vigorous consequence; for whenever a rise of the land has taken place one of two things has happened: the region affected has either gained an accession of mass, or a mere increase of volume without increase of mass." The former supposes a raising of the plateau against its own rigidity and its statical weight; the latter no overcoming of resistance; and hence, Mr. Dutton infers that the

cause of elevation, whatever it may be, involves the expansion of the underlying magmas and the cause of depression, their shrinkage.

4. *Siliceous bed consisting of Diatoms, Radiolarians and Sponge-spicules, in the Eocene of New Zealand.*—This siliceous bed of organisms, occurring on the east coast of the South Island of New Zealand at Oamaru, whose Sponge-spicules are described by Dr. G. J. Hinde and W. M. Holmes (in the J. Linn. Soc., 1892), is regarded as probably a deep-sea deposit, "comparable with the Diatom ooze which now forms a belt of varying width surrounding the South Polar Regions, between the Antarctic Circle and the 40th parallel," at "a depth of 600 to 1975 fathoms, and an average of 1477 fathoms. A bluish siliceous deposit now found off the same east coast at depths of 700 to 1100 fathoms is very different in consisting chiefly of material from the land with few siliceous organisms.

5. *A Preliminary Catalogue of the systematic Collections in Economic Geology and Metallurgy in the U. S. National Museum*, by FREDERIC P. DEWEY. 256 pp. 8vo. Washington, 1891 (Bulletin of the United States National Museum, No. 42).—This bulletin gives not only a full description of the National Museum collections, but also a valuable account of mining and metallurgical processes in the different parts of the country, illustrated by many admirable plates.

6. *The Palæontology of the Cretaceous formation on Staten Island;* by ARTHUR HOLLICK. Reprint from Trans. N. Y. Acad. Sci., vol. xi, 1892.—Dr. Hollick gives in this paper a brief summary of the various discoveries that have been made by himself and others of animal and vegetable remains on Staten Island. They consist altogether of eight species of mollusks and a dozen or more of plants, many of them in a bad state of preservation. They were found at Kreischerville, Tottenville, Eltingville, Prince's Bay, Arrochar and Clifton, in more or less ferruginous and concretionary matter underneath the bowlder drift or somewhat mingled with it and bearing evidence of considerable disturbance. Only at Kreischerville are the Cretaceous clays found in place. The shells are of marine Cretaceous type and the plants are characteristic forms of the Amboy clays of New Jersey across the Kill and the Raritan, most of which, however, were originally described by Heer from the Cretaceous of Greenland, or by Lesquereux from the Dakota formation. The plants were all found at Tottenville and Prince's Bay, and Dr. Hollick shows that their occurrence can be accounted for on the theory of glacial transportation from the well-known plant-beds of the Woodbridge district, but he thinks the marine shells of Arrochar, sheltered on the west by the Archæan ridge, do not admit of this explanation and must be regarded as in place. The paper is illustrated by four plates, three of which are devoted to the plants. The figures are remarkably clear and instructive.

L. F. W.

7. *Untersuchungen über fossile Hölzer Schwedens;* von H. CONWENTZ. Kongl. svenska Vetenskaps-Akademiens. Bandet 24, No. 13.—The vegetable remains described in this important memoir all come from the southern extremity of Sweden, sometimes called Scania, in which so many horizons are exposed that yield fossil plants, especially the Rhetic and the Pleistocene. Nilsson, as long ago as 1831, proved that there was a Tertiary plant bed at Köpinge, and now we have evidence of an Upper Cretaceous (Senonian) deposit, called the Holma sandstone, which contains coniferous remains consisting of silicified trunks in place and also lesser twigs and even well-preserved pine cones. Most of these belong to two species, both of which are regarded as new to science, which Dr. Conwentz here fully describes and illustrates in his thorough manner, both in their external characters and their internal structure, and names respectively, *Pinus Nathorsti* and *Cedroxylon Ryedalense*. The Holma Sandstone occurs on both sides of the Ryssberge north of the 56th parallel of north latitude.

Besides these remains in place the present memoir also describes a large amount of drift wood (Geschiebehölzer) from the extreme southern peninsula, much of which had long lain in the museums at Stockholm and elsewhere awaiting identification. Most of these proved to be coniferous, but wholly unlike the Holma Sandstone flora, having the Sequoia type of structure which is referred to Cupressinoxylon, or if roots, to Rhizocupressinoxylon. One piece, however, turned out to be a palm stem and was intrusted to Dr. Stenzel who is so great an authority on such forms. He describes it as *Palmacites filigranum*, a new species of fossil palm.

As regards the original source of those blocks of silicified wood, their systematic character is sufficient proof that they cannot be in place in the comparatively modern drift (Diluvian) in which they chiefly occur. They differ too widely from the forms found in the Holma Sandstone to make it at all probable that they belong to that age. The author concludes that they were originally derived from a formerly wide-spread Tertiary formation, the softer parts of which have been long since eroded away leaving only these heavy undestructible blocks of silicified wood which now lie buried under the superficial deposits.

L. F. W.

8. *On Penfieldite, a new species;* by F. A. GENTH. (Communicated by the author.)—While examining a lot of minerals, formed by the action of sea water on ancient slags which Mr. Geo. L. English collected at Laurion, Greece, I noticed a *very few* hexagonal crystals which proved to be a new species, for which I propose the name: Penfieldite, in honor to Prof. Sam'l L. Penfield the indefatigable worker in mineralogy and crystallography.

Hexagonal; generally in prisms with basal plane; the first pyramid is indicated by striation of the prismatic planes; a second obtuse pyramid appears on some of the crystals in small triangu-

lar planes. Some of the crystals are tapering at the ends and the basal plane is thus obliterated. The crystals with basal plane are generally dull, being coated with an opaque film, suggesting incipient alteration. Cleavage indistinct, basal. The tapering crystals from 0·5–1^{mm} thick and up to 5^{mm} long, the opaque from 0·5–2^{mm} thick and 2–3^{mm} long. Color white; luster vitreous, inclining to greasy. B.B. in a closed tube, gives *no water*, decrepitates and gives an abundance of sublimed lead chloride, soluble in water, leaving a yellowish white oxychloride. Easily soluble in dilute nitric acid.

Composition = $PbO \cdot 2PbCl_2$.

The analyses gave:

	1. Tapering crystals.	2. Opaque crystals.	Calculated
Cl =	18·55	17·94	18·21
Pb =	78·25	lost.	79·73
O =	----	----	2·06
			100·00

Associated with the Penfieldite is a mineral in long (up to 10^{mm}) silky needles, which largely volatilizes on heating, and *may* be another form of Penfieldite, or a new mineral; the other associates are anglesite and small quantities of laurionite.

Philadelphia, July 26th, 1892.

9. *Brief notices of some recently described minerals.*—Masrite is a fibrous kind of alum found in Upper Egypt and described by H. Droop Richmond and Hussein Off. It contains a small amount of cobalt and, as believed by the authors, a minute quantity of a new element for which the name *masrium* is proposed, after the Arabic name for Egypt. Assuming that masrium is a bivalent element, its atomic weight is calculated as 228, and it is regarded as belonging in the beryllium-calcium group in which group there is a place in the periodic system for an element with an atomic weight of 225. The analysis of masrite gave:

SO_3	Al_2O_3	Fe_2O_3	X[a]	MnO	CoO	FeO	H_2O	Insol.	
36·78	10·62	1·63	0·20	2·56	1·02	4·23	40·35	2·61	= 100

[a] X = Masrium oxide.—*Proceedings Chem. Soc.*, April 21, 1892; *Nature*, May 26.

Basilite is a hydrous manganese antimonate described by Igelström from the Sjö mine, Grythytte parish, Sweden. It occurs in steel-blue bladed forms with metallic luster, which it loses upon exposure; it is not magnetic. An analysis gave:

Sb_2O_5	Mn_2O_3	Fe_2O_3	H_2O	
13·09	70·01	1·91	15·00	= 100·01

For this the formula $11Mn_2O_3 \cdot Sb_2O_5 \cdot 21H_2O$ is calculated.—*Geol För. Förh.*, vol. xiv, 307, 1892.

SJÖGRUVFITE is a manganese arsenate, also described by IGELSTRÖM, from the same locality. It occurs in crystalline granules or seams in jacobsite. The color is light yellow, resembling some garnet, but its hardness is less. An analysis gave:

As_2O_5	Fe_2O_3	MnO	CaO	PbO	H_2O
49·46	11·29	27·26	3·61	1·74	6·81 = 100·17

It is not far from other manganese arsenates actually described, and it needs further examination to prove that it is a distinct mineral.—*Ibid.*

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters*, vol. viii, 1888–1891, 448 pp. 8vo. Madison, Wisc., 1892.—This volume contains besides other papers, the following on Physical, Geological, and Natural Science: Chamberlin, Additional evidences bearing on the Interval between the Glacial Epochs; W. M. Wheeler, On the Appendages of the first abdominal segment of embryo Insects (54 pages with 3 plates); C. D. Marsh, on the deep-water Crustacea of Green Lake; H. B. Loomis, on the effect of changes of temperature on the distribution of magnetism; E. Kremers, on the Limonene group of Terpenes (63 pp.); E. A. Birge, List of Crustacea Cladocera from Madison, Wisconsin, with a plate; besides papers by C. R. Van Hise and F. Leverett that have appeared in this Journal.

2. *A Dictionary of Altitudes in the United States*, Second Edition. Compiled by HENRY GANNETT, Chief Topographer. 393 pp. 8vo. Washington, 1891 (Bulletin No. 76, U. S. Geol. Survey).—In the new edition of this useful work considerable additional matter has been added, and the arrangement is changed, the places being in alphabetical order throughout instead of being grouped under the several States.

Through Mr. Gannett the Survey has recently issued an excellent colored contour-map of the United States.

Journal of American Ethnology and Archæology, edited by J. Walter Fewkes. Vol. ii, 194 pp. with several illustrations. This volume contains papers by the editor on a few Summer Ceremonials of the Tusayan Pueblos; Natal ceremonies of the Hopi Indians; Report on the present condition of a ruin in Arizona called Casa Grande.

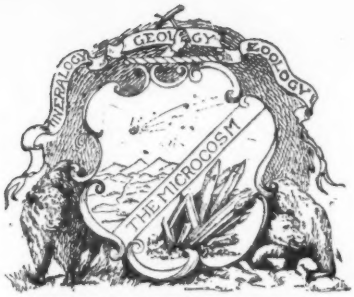
The Humming Birds, by Robert Ridgeway. This work of 150 pages, with 46 plates, is from the Report of the National Museum for 1890, pp. 253–383.

Silk Dyeing, Printing and Finishing, by G. H. Hurst, F.C.S., 226 pp. 12mo, with 11 plates of samples of colored silks. London, 1892.—George Bell & Sons, London and New York.

Principles of the Algebra of Physics, by A. Macfarlane, Fellow of the Roy. Soc. of Edinburgh, Prof. Phys. Univ. Texas. 117 pp. 8vo. Salem, Mass.—Salem Press Publishing and Printing Co.

The Optical Indicatrix and the Transmission of Light in Crystals, by L. Fletcher, M.A., F.R.S. 112 pp. 8vo., with 21 wood cuts. London, 1892.—Henry Frowde; Macmillan & Co., New York.

Annuaire Géologique Universel: Revue de Géologie et Paléontologie, by Dr. L. Carez et H. Douvillé, Année 1890, Tome vii, 42 Fascicule. pp. 817 to 1158. Paris.—Comptoir Géol. de Paris.



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J. WILEY & SONS, New York.—**System of Mineralogy** of J. D. DANA. 6th edit. by EDWARD S. DANA. lxiii, 1134 pp. large 8vo., 1892. $12.50. 5th edit., 1868, with three appendices, 1872, 1875, 1882. $5.00.—**Manual of Mineralogy & Lithology,** by J. D. DANA. 4th edition. 517 pp. 12mo., 1887.—**Text-book of Mineralogy,** by E. S. DANA. Revised edition. 512 pp. 8vo., 1883.—**Text-book of Elementary Mechanics,** by E. S. DANA. 300 pp. with numerous cuts, 12mo., 1881.

DODD & MEAD, New York.—**Corals and Coral Islands,** by J. D. DANA. 440 pp. 8vo. 3d ed., 1890.—**Characteristics of Volcanoes,** with contributions of facts and principles from the Hawaiian Islands, by J. D. DANA. 399 pp. 8vo. With illustrations, maps, etc. 1890.

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